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ABSTRACT

The purpose of this paper is to gain insight into the nature of the reading process through an understanding of the general nature of sensory processing mechanisms which reorganize and restructure input signals for central recognition, and an understanding of how the grammar of the language functions in defining the set of possible sentences in the language. Chapter 1 discusses neural coding in perceptual processing systems and explores such topics as short-term memory and developmental and learning factors which affect central human processes. Chapter 2 discusses linguistic theory on the nature of the language system and two models of perceptual processing. Chapter 3 discusses similarities and differences in decoding strategies for oral and written language inputs. (TS)

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PERCEPTUAL DECODING PROCESSES FOR LANGUAGE IN A VISUAL MODE AND FOR LANGUAGE IN AN AUDITORY MODE

QUALIFYING PAPER

SUBMITTED BY

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OCTOBER 1974

Harvard University
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INTRODUCTION

The purpose of this paper is to gain insight into the nature of the reading process. To do this one needs to understand the general nature of sensory processing mechanisms which reorganize and restructure input signals for central recognition processing. One also needs insight into how the grammar of the language functions for defining the set of possible sentences in the language. Therefore this paper will search for an understanding of how written messages are processed by the adult reader, by surveying research on the nature of neural coding systems, research showing the special nature of the central language processors, and research showing how adult linguistic-competence relates to the task of understanding the spoken and the written message. Recent linguistic theory will serve as a framework for describing similarities and differences in the nature of the input cues in the oral language signals and in the written English texts. It is hoped that a deeper understanding of the relation of the two signaling systems may be of aid in understanding what needs to be taught in reading instruction. As Chall (1969) has stated, "the crucial question for reading instruction is how these linguistic data are to be used" (p. 560).

It is almost seventy years since Huey (1908) published his book on the psychology of reading. At that time Huey related psychological knowledge of visual processes to the deeper processes involved in comprehending language in its written and oral forms. In his introduction to the 1968 M.I.T. Press reissuance of Huey's book, Carroll observes that after Huey, the reading research of Vernon, Dearborn and Anderson, and Woodworth shied away from "some of the deeper questions that Huey raised about what it means to perceive printed words or indeed to comprehend language spoken or written" (x-xi). In 1957, Chomsky proposed a transformational grammar to describe

the form and organization of the linguistic code that a listener has internalized for relating sound to meaning when processing language. In "Language by Ear and by Eye" (1972), one finds that recent work in generative grammar has enabled scholars to again address deeper questions about the nature of the English orthographic code in relation to that of the oral language system.

The reader of a written text like the listener to a spoken message perceives the semantic content of the sentences; he is not conscious of the shape of the letters or the sounds of the words. One might consider mature reading like a marriage of visual recognition processes and oral language competencies. In order to question the nature of the decoding processes for language in a visual mode and for language in an auditory mode, one needs to examine not only the general properties of peripheral and central neural coding systems, but also the nature of the internal knowledge that the central processor brings to the decoding task. Recent research on neural processes shows that recognition is an active process in which the organism uses innate and learned factors for abstracting the necessary relevant features from the input signal (Held and Richards 1972, Uttal 1972, Turvey 1973). In any human cognitive task, a percept cannot be separated from the perceptual processes used for organizing the input stimuli. Recognition involves higher cortical functions and these in turn, involve the system of knowledge that the processor has already mastered.

The work of Read (1970) shows that young children use their oral language knowledge for representing ideas on paper. Read's evidence was taken from the invented spellings of children between the ages of three and six. He shows that even very young children use the generalizations that they have made about their oral language system when they represent their ideas on paper.

Read found that in their invented spelling system, children ignored certain predictable phonetic differences. For example, even his youngest children used as part of their writing system, one letter, "s," to mark the concept plural. Thus the letter "s" represented the -/s/ -/z/ sound-alternation of English plural nouns. Berko's work (1961) has shown that this abstraction that Read's children showed in their invented spellings is a part of the children's oral-language system. Thus Read's children did not mark in their writing a sound difference which was predictable by using the knowledge that the children had acquired about the English phonological system.

What is known of the form and organization of the adult's grammatical system? Modern linguistic theory makes certain hypotheses about the structure of the adult-speaker's oral language code. Jakobson's work (1968 translation from a 1941 German text) on the phonological structure of spoken language stresses that the system of signs underlying oral language has a hierarchical structure to its units, with the phonemes being the basic building blocks of oral linguistic expressions. The phonemes consist of a small set of contrastive (i.e., distinctive) features; phonemes carry no meaning, but are the abstract units underlying the sound structure of the lexically and grammatically meaningful morphemes. It is the morphemes which are organized into a hierarchy of higher-order linguistic categories whose structure is specified by the syntactic and semantic system. Thus lexical morphemes are organized into nouns, verbs, adjectives which are recoded into noun phrases and verb phrases; these phrases are structured into the clauses, the sentences, and finally into the paragraphs of dialogues. Chomsky (1965) and Chomsky and Halle (1968) give a formal description of the adult's linguistic competence in terms of the basic syntactic units of the sentence and the system of rules used to transform deep structured ideas

into their oral expression. The theory describes the knowledge the decoder needs for forming a structural description of the syntactic relations of the words in a spoken or written sentence. Liberman (1970) shows that there is a complex speech-encoding process by which the abstract phonological representations are transformed into the spoken signals received by the hearer of the message. This research silhouettes certain differences between the form of the acoustic speech signals and that of the written alphabetic code, differences which will be shown to be important for understanding the nature of the beginning reader's task.

Reading instruction normally assumes that the pupil possesses audio-oral knowledge of the language system. Jakobson (1967) reminds one that the written system is a "superstructure" built upon the spoken language system. Therefore one can expect to find similarities and differences in the two decoding process-tasks. Indeed R. Brown (1970) has observed that studies on reading which focus on the means by which the reader comprehends the written text (such as those of Weber 1970, Levin and Kaplan 1970, Hochberg 1970) resemble studies on speech-perception processes (such as those of Fodor and Garrett 1967, Brown and McNeill 1966). When Thorndike (1917) studied the errors that children made in answering his written questions about a series of paragraphs that the children had just read, he concluded that "reading is reasoning." He noted that factors such as a simplification , or an incorrect analysis of the organization and the relation of the written ideas frequently underlay the children's misunderstandings. Thus when a reader needs to recover semantic information from a series of sentences, be the input oral or visual, he must be able to accurately use his knowledge of the grammar of the language if he is to successfully interpret and recall these messages (Liberman, Mattingly, Turvey 1972). Therefore an

explicit theory describing the nature of the relations of the words of a sentence can help in understanding what underlies the ability to extract a semantic meaning from the sentences.

Certain similar cognitive factors seem to limit the adult's oral and written sentence processes. For example, people can be trained to understand spoken English sentences in discourse which has been speeded-up from two hundred to four hundred words per minute (Orr, Friedman, Williams 1965). One finds that the normal adult reading rate is usually from two to four hundred words per minute. Individual differences also affect performance in oral and written language processing tasks. Sticht (1972) found similarities in the oral and written language decoding ability for men of low and of average mental aptitude (as measured by the Armed Forces Qualification Test). Sticht tested these men for their ability to comprehend auditorily and visually passages of 6.5, 7.5, 14.5 grade levels of readability. He found a similar listening and reading comprehension score for each mental-aptitude group. Sticht concluded that certain reading difficulties for adults may be due to "reduced ability to comprehend language" (p. 288).

Despite the fact that certain similarities can be shown between the decoding of oral and written language inputs, the processing of a language message presented to the eye differs in fundamental ways from the task of decoding a spoken message. The acoustic input cues arrive sequentially over time, while in reading the information the skilled reader may utilize central and peripheral visual information to aid in locating on the page the "distal address" of key information and regress to check data (Jakobson 1967, Hochberg 1970). There are also differences in the information represented in each of the two types of language message systems; for

example, intonation and stress are not indicated in writing, whereas writing resolves some forms of homophony presented in speech (Lieberman 1967, Klima 1972). But most important of all is the fact that the two signal systems represent structurally different levels in the hierarchical organization of the linguistic code of English (Chomsky and Halle 1968). A comparison of the function of the cues in the oral and written signal systems will show certain differences in the information signaled by the letters of a word and the speech sounds. The sign value of the letters of a word can only be understood by studying how letters function in higher-order linguistic units.

Any analysis of written and oral language processing systems must face the problem that despite the wealth of information in any stimulus, the central recognition processes have a finite capacity (Miller 1956 and 1972). Therefore one must describe the systems for abstracting from the external signals the features necessary for recognizing the input stimulus.

In this paper, Chapter I will show that species-specific neural systems organize and restructure sensory input extracting from it specific sets of features which are necessary for higher level processing. Chapter II will discuss the generative theory of the structure of language as it relates to reading. An important part of this theory are the explicit claims about the units and the system of rules that the speaker-hearer has for processing sentences. This formal description of the hierarchy of psychologically significant levels of language knowledge will be used to give new insight into certain fundamental differences between the code used for spoken language and that for the written one. The second focus in Chapter II will be on models of human information processing. One model will describe human perception as resulting from passive processes, the second model claims that people understand sentences because they are able

to generate the processes by which the sentence was structured. These models will be evaluated against the nature of language comprehension processes in the reading task.

Chapter III will question the similarities and differences in the strategies a skilled reader uses for understanding an oral or a written text. The hypotheses given in Chapter II about the content of language knowledge and the nature of visual and oral language processes will be used as a framework for relating observed speech and reading behaviors to the input signals. This chapter will discuss the nature of cues in the linguistic signal that enable the processor to construct a meaning from the given sentence. Specific decoding strategies used in actual performance acts will be questioned, and form-function differences between the orthographic cues and those of the spoken language will be described.

Chapter I

NEURAL CODING IN PERCEPTUAL PROCESSING SYSTEMS

Introduction

The problem in describing the reading process is how to understand the organization of the systems a reader uses for extracting meaning from the printed page. In this chapter the focus will first be on how both peripheral neural systems and central cortical processes organize input stimuli. It will be shown that developmental factors and learning affect an individual's information processes by affecting the central schema for structuring input data. Then it will be shown that linguistically encoded stimuli are processed by special processors in the human brain so that one needs to ask special questions about the act of perception when the input is a spoken or a written message.

There is a long historical precedent for distinguishing between two aspects of information processing. In the 19th century, Wundt distinguished between apprehension, a peripheral processing of elementary sensations, and apperception, the actual recognition or awareness which Wundt believed required a certain level of attention. Twentieth century researchers such as Neisser (1967), Atkinson and Shiffrin (1968), and Turvey (1973) on visual processing or Crowder and Morton (1969) on oral-language processing also propose two stages in their information-processing schema. They distinguish between a preattentive process and a central process. The preattentive process results in the encoding of information in an iconic or buffer storage level. This contains data of short duration, analyzed into global sets of context-independent features. The central, selective

focal-attention level differs from the icon storage stage in that factors such as frequency and learning as well as duration and intensity of the input stimuli may affect the percept.

First this chapter will review recent neurophysiological research on peripheral neural coding systems to know that before sensory-input stimuli are recognized by the central processor, innate, species-specific sensory filtering operations reorganize visual and acoustic stimuli recoding these stimuli into specific sets of features. The second section of the chapter describes certain characteristics of human central processors. With regard to central decisions, Miller's work (1956 and 1972) shows that the human brain is limited in the number of units it can attend to at one time so that in order for the information given to the central processors to be content-rich, it must have already been drastically recoded. Turvey's study (1973) of the interface between peripheral and central processors in letter recognition tasks shows that perception involves a series of operations over time with central processors recoding the crude features abstracted by the peripheral processors. The work of Attneave (1967), and Pritchard (1972) show that developmental factors affect the characteristics used in central matching to pattern processes.

The final section of the chapter focuses on the special cortical system used when the input stimuli is linguistic. Evidence as to how central processes operate with linguistically encoded signals will come from dichotic listening studies, in which subjects simultaneously receive two acoustic signals one into each ear, and from research using synthetic cues to elicit a subject's language percepts. The evidence from these studies will be used to explain certain fundamental differences between the form of the signal system of the spoken language and that of the English

alphabetic system. Evidence of functionally independent linguistic structures will be shown from aphasic research from studies on slip-of-the-tongue errors made by normal adult speakers. Aphasic data will also be used to show that normally an individual's reading ability is dependent upon intact oral language processors.

1. Species-Specific Neural Constraints on Sensory Processings

Held and Richards (1972) define perception as "the process of knowing objects and events in the world by means of the senses" (p. 166). They stress that the relation between any stimulus input and the resultant behavior is complex and indirect because the neurophysiological structure of the systems of perception is such that the brain never gets an exact "copy" of the objects as they are in the external world. Part of any perceptual processing system involves selectively abstracting sets of data from the incoming stimuli. Furthermore, different species may differ in their processing systems so that, in a sense, different species perceive different "worlds." Whenever species-specific characteristics are part of the organism's neural processing system, this will result in specific features being abstracted from the input-signal in ways that may differentially affect behavioral responses.

Capranica, Frishkopf, and Goldstein (1967) report on the close relation between a male bullfrog's neural acoustic feature filtering system and his behavioral response to certain sound stimuli. Capranica found that the male bullfrog's mating call response is evoked whenever the input sounds contain at least a minimum amount of energy in certain critical low and high frequency regions. However Capranica also found that the bullfrog will be inhibited from making this croaking response whenever one adds to the input-signal sufficient energy in the intermediate-frequency range.

The work of Frishkopf and Goldstein had earlier shown that the bullfrog's afferent acoustic pathways have specific activating and inhibiting responses to these critical tones. Thus the bullfrog's behavioral responses depend upon the fact that his acoustic perceptual mechanism has a special system for encoding the presence and the absence of specific frequencies in the acoustic input stimulus.

Eimas et al. (1971) found that human infants as young as one month of age can discriminate between synthetic acoustic-cue signals for pa/ba syllables. These experimenters took synthetic speech in which they varied the acoustic cue from p to b in small steps. They studied how small changes in the acoustic signal affected the infant's sucking pattern, knowing that an infant's sucking patterns discriminate between stimuli. They found that the infant's sucking pattern changed for certain acoustic differences and not for others. These cues to which the infants were sensitive were in that range of differences that in spoken language signal the difference between a voiced stop and a voiceless stop. They concluded that the infant's perceptual system seems to be sensitive to acoustic differences that function as cues for linguistically significant information.

The studies of Hubel, Wiesel, Lettvin, and Muntz on the operations performed by the frog's retina have shown that there are species-specific responses to visual signals which depend upon peripheral neural processors extracting certain complex patterns or features from the visual input signals (Muntz, 1972). Tinbergen (1951, as discussed in Klopiter 1973), too, showed that some species are "predisposed" to learning to respond to certain environmental stimuli in a species-specific way. Work on animal "imprinting" behaviors shows that the emergence of behaviors fundamental for the survival of the organism, depends on the organism developing the ability to discriminate and to classify certain features in the input stimuli and on the presence

in the organism's environment of such stimuli at the "critical" time (Hess, 1972; Klopiter, 1973).

Neurophysiological studies on perception and on receptive fields show that input-stimuli are reorganized and recoded as they are processed. For example, the human visual system has primitive networks which are sensitive to color, brightness, contour, and line direction (MacKay, 1967 and Kolers, 1967). The work of Hubel and Wiesel and Lettvin shows that this reorganization of sensory data results in the decomposition of the input information into sets of data which are finally processed in different areas of the cortex (Hubel, 1972). Thus not only may neurons have species-specific selective responses to special features of the acoustic and visual input stimuli, but also, as neural systems converge from the peripheral receptors to the central nervous system, the processing results in species-specific modification, reorganization, and compressions of the input by systematic coding (Held and Richards, 1972). Studying the chemistry at synaptic junctures, Michael's research (1972) shows that specific features in the external stimuli will cause certain neurons to either fire or else be inhibited from firing at synaptic connections. This results in a more abstract coding of the information in the input stimulus. Held and Richards (1972) describe this as a coding process by which at each synaptic connection the input data are"whittled down"as it is structured for the central processors.

2. Short Term Memory, Developmental and Learning Factors Affect Human Central Cortical Processes

Since people have restricted short term memory capacities for focusing on incoming stimuli, Miller (1956 and 1972) states that organization and

symbolizing enable people to pack more information into each unit processed by the human brain's central processes. At any one time, people are able to attend only to a finite number of symbols; people are also limited in the rate at which they can process a series of unrelated symbols and in the judgments that can be made about the content of such input. Given these severe restrictions on short-term attentional processes, Miller concludes that it is only by the use of encoding systems, which abstract and restructure the relevant information in the input, that each symbol processed by the central processor becomes "informationally rich." It is this ability to abstract from the input signals specific features and to recombine them in specific ways that results in an increase in the actual amount of information that the central processor receives per unit-input.

Lieberman (1973) emphasizes the efficiency of the speech code for the transmission of semantic information. In decoding speech, people process phonological segments at the rate of 20 to 30 phonological segments per second while people, at best, can identify sounds at a rate of seven to nine per second. With regard to the efficiency of linguistic encoding of stimuli in visual processing tasks, Kolers (1970 discussing Kolers and Katzman, 1966) notes that adults can correctly recall only four letters in their correct order if the letters are flashed in rapid sequence on a fixed point of a screen. Yet, when reading a text, adults easily process the same number of words per second. Such rate processing differences show that people, in decoding sentences, work with units larger than individual sounds or letters; sentences are being processed in terms of higher order syntactic units (phrasal and clausal structures) and not in terms of the individual letters or sounds of each word.

Turvey's work (1973) set out to study the interface between peripheral and central processes in visual recognition tasks. He found that higher order knowledge affects peripheral perceptual processes. Turvey performed a series of visual recognition tasks using monocular and binocular conditions (two stimuli are presented in succession to one or to two eyes) and dichoptic conditions (one stimulus is presented to one eye and a second to the other eye). He studied subjects' ability to identify a briefly exposed target stimulus when it was either followed or preceded by a second stimulus (the mask). Turvey concluded that peripheral and central visual processes are related in a "concurrent and contingent fashion." He found that letter recognition involved a series of central operations over time. Central decision is dependent both upon the output of the crude, context-independent feature analysis performed by "parallel nets" in the peripheral systems, and upon central recodings which enable the processor to relate input data to stored information.

Turvey concluded that semantic properties as well as the geometric-form of the stimulus affect central reading recognition processes. He based this conclusion upon his own work and upon that of Mayzner and Tresselt (1970) who showed that a target consisting of a five-letter word cannot be masked by a mask containing a string of five unrelated letters while the same conditions result in the masking of a five-letter non-word target. Turvey's experiments also show two factors that are helpful in understanding the differences in individual reading skills. Turvey found that there was variation in the rates at which each of his subjects performed central visual processes but he found no significant variation in his subjects' peripheral processing rates. This implies that individual adults differ naturally in their central processing rates. Furthermore, Turvey's data shows that central processing

rates improve with practice, his experienced subjects made central decisions much more quickly than did his unexperienced subjects. Thus one sees that practice improves central recognition rates.

Turvey's work shows that feedback systems affect ongoing perceptual processes. Held and Richards (1972) in their review of recent research on neural systems, also have concluded that feedback systems must be part of any mechanism explaining input-output behaviors. Thus part of the process for organizing any percept involves the perceiver's actively using his knowledge of past experience. Agreeing with Held and Richards, Neisser (1967, p. 3) states that, "the world of experience is produced by the man who experiences it." MacKay (1972) quotes Whitfield's and Jung's research on neural systems which showed that efferent fibers are involved in most sensory-input pathways, thus again implying central controls may be affecting peripheral neural processes.

Pritchard's work (1972) is interesting to examine, for it shows how learned categorizations affect perception. Pritchard found when he stabilized images on the surface of the human retina, that as the images were fading and so were no longer complete, the structure that his subjects saw depended upon what the subject knew about the object that had just been seen. Thus a profile of a face would fade in such a way that the subject reported seeing only the nose and the chin, or else only the eye and the upper part of the skull etc.; the face seemed to fade in a way that only meaningful units were left. A monogram like would fade by decomposing into either the units "H" and "B" or else into a "3" and a "4", again into meaningful units. A word like BEER might fade into PEER or PEEP or BEE or BE. Norman and Lindsey (1972) observes that, in Pritchard's experiments, "the more meaningful the image, the longer it lasts" (p. 35).

Attneave (1967), too, observes that form perception depends heavily on learning and he wonders about the form of the information stored in memory. Menyuk (personal communication) finds that the process Pritchard describes is one of pattern matching to sample. Attneave invokes a principle of "like-facilitating-like" to explain Pritchard's closure phenomena as well as to explain the process of recall of image memories.

It is important to realize that the categories available to the subject in pattern recognition will change with maturation. Ghent (1961) found developmental changes take place also in the effect that visual environment has on the way children process visual forms. She studied the way children feel about "the right side up" for sets of geometric shapes. She concluded that four-year-olds seem restricted to using the orientation of the figures on their retina as the frame of reference for making judgments, but that older children's judgments were affected by surrounding environmental factors. Thus for the older children relational factors and not just sequential considerations were affecting their perceptual processes. Her older children had developed the ability to compare "how the perceived form relates to other forms and their environments" (p. 187). The ability to focus both on the features of a visual form and on its environment relates to the ability to use the entire shape of a word, an important factor in reading processing.

3. Language Specific Cortical Structures

a. Central processing and the oral speech articulatory code

Research on how the human brain organizes the input-sound data shows that people process speech and nonspeech sounds in different hemispheres. Milner's work on hemispheric specialization shows that man's brain is unique

in that each cerebral hemisphere performs special functions. For most people (except some left-handers) the left hemisphere is involved in speech processing and in skilled motor movements. Using Broadbent's dichotic listening technique for overloading normal subject's language-processing mechanism, Kimura (1973) shows that people use different cortical hemispheres for processing speech and nonspeech sound-inputs. The left hemisphere is superior not only in the processing of language-meaningful sounds but also for processing nonsense syllables and even for processing an input in a language foreign to the listener and being played in reverse. Kimura found that the right hemisphere has the complementary specialization for processing music melodies and sounds that are nonspeech ones.

Furthermore people process cues for consonants and for stops differently. The dichotic-listening study of Spellacy and Blumstein (1970) did find that for nonsense CVC syllables, vowel lateralization could be influenced by whether the context was linguistic or nonspeech noises. However this study showed that consonant perception was always lateralized in the left hemisphere, independent of context. Working with normals and with alcoholic patients who have a severe memory disturbance (Korsakoff patients), Goodglass and Peck (1972) studied the differences in word-storage capacity between the right and the left hemispheres. They used a dichotic listening test in which they varied the order of ear reporting. They found that the right hemisphere is less efficient than the left as a storage mechanism and that the Korsakoff patients had a larger difference between the two hemispheres than did the normals. Goodglass and Peck could not conclude from this study whether the differences resulted because the two hemispheres have the same percept for verbal material but different rates of decay or because the hemispheres differ in percept constructs.

A. Liberman et al. (1967) studied the difference in the normal adult's ability to perceive stops and vowels. This work was done by giving the subjects synthetic acoustic cues for stop-consonants and for vowels. Liberman et al., studied how varying the acoustic stimuli affects the subject's specific language percept. They found that while people are able to hear the differences in a wide variety of synthetic vowel-cues, the stop-cues were only perceived categorically. (By categorical perception, Liberman et al. mean that there is discontinuity in a subject's perception despite the fact that they receive a continuous progression of changes in the acoustic cues). When Liberman et al. gave a series of different synthetic stop acoustic-cues to their subjects, they found there were quantal jumps in the subject's perception with slight changes in the acoustic signals when the changes were at the phonemic boundaries between two stops. While subjects showed sharply defined changes in perception for consonant-stops when the cues were at the boundary between two phonemes, Fry, Abramson, Eimas, Liberman (1962) had found that vowels are not perceived categorically. They did not find sharply definable acoustic bondaries distinguishing each vowel-phoneme percept. Their subjects' percepts were affected not only by the formant structure of the synthetic vowel-cues, but also by the other vowels present in the message. This shows that a listener's identification of any one vowel phoneme in a speech message is made in relation to the speaker's entire vowel system.

Crowder (1972) too stresses that there are fundamental differences between consonant and vowel perception. He refers to the work of Fujisake and Kawashima (1969) which showed that the presence of another vowel affects vowel perception but that the presence of a second consonant does not influence a subject's consonant perception. Crowder concludes that vowels

can stay undecoded in echoic memory while stop cues are immediately decoded and identified. Thus he too implies different central mechanisms for vowels and for consonants.

Discussing the special properties of the central speech processors, A. Liberman emphasizes that, in synthetic speech, stop-consonant acoustic cues can be recognized as linguistically meaningful units only when they are part of a syllable (1974 a and b). When a subject hears an acoustic cue for a stop, isolated from the steady state vowel-formant cues, then these stop-cues are perceived as chirps or glissandos and not as a linguistic signal. Therefore, since stop acoustic cues must be folded into the vowel cues in order that a subject recognize the sound as a linguistic one, Liberman concluded that the human brain's speech decoding system operates with input-units whose minimum size is syllabic. Liberman based this conclusion that the syllable is the unit of perception on evidence from Liberman et al. (1952). This earlier study showed that a subject's categorical stop percept required that the shape of the synthetic acoustic cues perceived as a specific stop depends not only upon the vowel of the syllable but also upon whether the stop precedes or follows the vowel of the syllable. Liberman (1974a and b) shows that the shape of the transition cueing the stop of the syllable "ba" is the mirror image of that cueing "ab." Thus the categorical perception of stops depends upon the hearer receiving both the acoustic cue for the stop and for the vowel of the syllable and the shape of the cues gives the perceiver a tag for the phonemic sequence. Kimura's work (1973) with dichotic listening caused her to decide that the basic unit of speech is the syllable since the syllable is the minimum signal giving right ear superiority in dichotic listening tests.

This research on speech perception highlights two fundamental differences between the form of the acoustic speech input signals and that of the written ones. In the first place certain features of the acoustic cues result in the central analyzing mechanism subclassifying together certain groups of sounds. For example, Liberman has shown that the acoustic cues for vowels share certain features which cause the vowels to be processed in a manner distinctive from that used for stop-consonants. However, the written shape of vowel-letters shares no common distinctive feature that would cause the visual analyzing mechanism to categorize them as a class distinct from all consonant-letters. Thus in the written cues, the central processor does not receive the same information about the structural relations of the units that he gets in processing oral language signals. Liberman's research shows a second difference between the oral and written coding systems, namely that the speech-encoding process results in the hearer receiving units whose transmission size is approximately syllabic, while the basic units in the English writing system are the individual letters. Thus one realizes that in first learning to read the written code, the child must bring to conscious awareness a knowledge of the segmental units underlying the syllabic structure of his spoken words. Another way to state this is that the child needs to recognize that the writing code does not represent certain encoding operations that he uses for speech transmission. It is interesting to find that recent beginning-reading instruction is experimenting with syllabaries. Believing that syllables are "more natural units," Gleitman and Rozin (1973) are using an introductory reading system built on figures and written syllables in order to help children discover the less available, more abstract phonemic segments that underlie their spoken words. I. Liberman (1973) and Elkonin (1973) discuss alternative

teaching methods to help children discover how to segment their spoken speech into its constituent consonant and vowel segments. The Illinois Test of Psycholinguistic Abilities and the Roswell-Chall Blending Test have shown that some children have great difficulty in learning to realize that they can blend individual sounds into syllables and words.

b. Further evidence of structural specificity of language area from slip-of-the-tongue errors and from aphasic losses

Lashley (1961 reprint of a 1951 speech) predates Chomsky's theory of the nature of language knowledge. Both hypothesize a hierarchical organization underlying language with an autonomous syntactic component relating the semantic meaning and the phonetic form of a sentence. Lashley set out to explain the dynamics of the organizational schema underlying a speaker's ability to give oral expression to his idea. He used as evidence for his conclusions slip-of-the-tongue errors, typing mistakes, and language losses in different types of aphasia. In order to account for this data, Lashley found that he had to hypothesize that three or four major neurological systems interacted to determine the grammatical form of the sentence, the content words of the sentence, and the ordering of the individual articulatory-motor units.

Fromkin (1971, 1973) studied the linguistic constraints underlying the slip-of-the-tongue errors which she had collected over a three-year period. She concluded that a speaker sets the grammar and the intonation contour of the phrase of the sentence and into this he inserts the lexical items. The lexical items must be precategorized as nouns, verbs, or adjectives since she found that in word-substitution errors, nouns were substituted only for nouns etc., while, in morpheme substitutions, roots change places with other roots and endings changed places with other endings. Thus from her data she

suggests that the adult's lexicon stores words in terms of stems and affixes. This is an important point and it will be considered later in relation to the English orthographic code and the adult's reading process.

Aphasic disturbances show that there is a certain neurological autonomy to both syntactic and to lexical processes. Aphasia research shows that unilateral cortical lesions focally located in the language area of the left hemisphere result in specific forms of language impairment. A left frontal lesion located in Broca's area, the area lying just in front of the hand and face cortical motor strip, will result in the patient's being able to comprehend spoken language reasonably well, but the patient is impaired in his ability to express ideas. This impairment is not merely articulatory, but rather it is to the patient's ability to use syntactic organization and syntactic markers (Myerson and Goodglass 1972, Zurif, Caramazza, Myerson 1972). A Broca's aphasic's relatively good preservation of language comprehension and his fluctuations in speech performance acts has led Lashley (1961) to conclude that the impairment is due to an inability to fully integrate to the active level certain of the neural systems that underlie normal verbal expression.

In contrast to the Broca's difficulties in using grammatical structure, a lesion in Wernicke's area, the cortical area located in the posterior part of the left temporal lobe adjacent to the primary hearing center (an area that Luria (1966) identifies as being the division of auditory cortex responsible for the auditory analysis of speech), will result in the patient's speech being fluent. However, in contrast to the Broca's aphasic, the Wernicke's aphasic is very poor at understanding language. Furthermore despite the fact that the Wernicke's speech abounds with complex phrasal structures, it lacks logical relations between the strings of phrases. His

speech also contains frequent lexical and grammatical substitution errors. Thus the Wernicke's profuse verbal outpourings convey almost no information to the listener. Luria (1966) stresses that a Wernicke's aphasic's damage is not in primary hearing but to the ability to discriminate the abstract phonemic features of speech. The patient may fail to differentiate phonemes that differ only in one distinctive feature, so that one finds that the Wernicke's aphasic is poorest at understanding the meaning of a word when it is spoken in isolation.

With regard to the relation between oral language and reading skills, Schuell and Jenkins (1[illegible] showed from their analysis of data from over four hundred aphasic patients, that regardless of the locale of the lesion, whenever an aphasic improves in his ability to use vocabulary and syntax, the improvement was reflected in his reading and writing performance. Luria (1966) concludes from studying his aphasic patients that with speech disorders resulting from cortical lesions in the language area, reading disturbances always result. He also observes that the patient's reading will "inevitably reflect the general features of the abnormal neurodynamics" of his language system (p. 413). Luria explains the Broca's reading disturbance as resulting from an inability to blend letter-sounds into syllables or words. A Broca's aphasic may be able to name the individual letters of the word and still fail to read the word because of this inability to "perform the necessary kinetic synthesis" i.e., to blend the sounds into a word. Luria finds that the patient will guess at the meaning of the word by using some of the letters as cues.

In contrast to the Broca's aphasic's difficulty, Luria finds that the Wernicke's aphasic may be able to recognize certain familiar words such as his own name or the name of his home town. However the Wernicke's patient

cannot name letters, or read aloud nonsense syllables, or read sentences. Thus Luria believes that the Wernicke's aphasic preserves only the ability to read words that he knows so well that they are perceived directly like an "ideogram." Von Stockert (1972) tested preservation of reading in a subtle way. He showed that Wernicke's aphasics seem to be able to use their knowledge of phrase structure to aid them in putting together short written sentences which had been divided into non-constituent parts. When he gave the patients three cards: the park boy walked to the , Von Stockert found that they performed better in constructing the sentence than they did when he gave them the task on three cards in which the sentence was divided into its constituents such as: walked the boy to the park .

Luria's (1966) studies on higher cortical functions in speech processes led him to conclude that one cannot consider the receiver of a speech message to be passively processing the input; rather "sensation is an active reflex process" in which the perceiver selects "the essential (signal) components of the stimuli" and inhibits the "non-essential, subsidiary components" (p. 97). Central effector mechanisms participate in tuning the peripheral receptor apparatus "as well as (in) carrying out the selective reaction to determine the components of the stimulus" (p. 97). Luria cites Blinker's study of anatomical connections and neuronographic investigations of human cortical connections, as evidence confirming this involvement of motor processes in speech perceptual acts. These studies showed that bundles of cortical fibres in the arcuate fasciculus connect the auditory association cortex of the temporal lobe (including Wernicke's area) to the inferior regions of the frontal lobe (including Broca's area) so that "conditions are created for the auditory and motor analyzers, especially those parts of

the latter concerned with the innervation of the vocal organs, to work together" (Luria, p. 99) in processing speech.

Summary

The purpose of this chapter was to question the organization of peripheral and central neural coding systems. It was shown that innate neurophysiological systems restructure sensory input data; furthermore learned categorizations affect ongoing perceptual processes. Eimas's work showed that a one-month-old child's perceptual mechanism is sensitive to fine changes in the acoustic signal changes which, in speech acts, are used to signal phonemic differences. Research on adult perception of synthetic speech shows the syllable to be the unit of transmission for oral speech. Therefore a child, who is learning to read English, needs to become consciously aware of the separate phonetic units that have been blended into the spoken syllables. This will aid him in making correspondences between the individual letters of the written code and the sounds of his spoken system.

Humans have special central systems for organizing language. Aphasic and tip-of-the-tongue studies showed that syntactic and lexical components involve semi-autonomous central processes. Aphasic studies also showed the dependence of reading competence upon the neurodynamics of the patient's spoken language system. Finally, Luria's analysis of cortical to cortical connections caused him to conlcude that motor fibers are involved in language perceptual processes, showing that efferent systems affect speech perception processes.

Chapter II

LINGUISTIC THEORY ON THE NATURE OF THE LANGUAGE SYSTEM AND TWO MODELS OF PERCEPTUAL PROCESSING

Introduction

The first chapter of this paper has described certain general features of peripheral and central neural processing systems, and also special features of neural structures used specifically for processing l nguage signals. The aim of this chapter is to evaluate models for information processing in relation to the nature of the oral and written language systems. One might consider the reading process as a marriage between two perceptual processes: one that of decoding spoken language and the other that of visual form recognition. Therefore this chapter will first discuss Chomsky's generative theory of language because this will provide an explicit description of the nature of the linguistic knowledge that a speaker-hearer must possess in order to be able to understand speech-messages. This theory will be found to provide insight in the special nature of the orthographic code. In the second main section of Chapter II, two current models of human information processing will be analyzed. The first proposes a passive processor and the second hypothesizes that the processor actively organizes incoming stimuli. These two models will be used as a framework for contrasting the demands on the internal processor when the stimuli are patterned forms against the demands when the input are linguistically encoded cues.

1. Generative Theory of Language Structure and the Orthographic Code

Chomsky (1957, 1965) and Chomsky and Halle (1968) have constructed a theory of the nature of linguistic competence. Their theory of the linguistic

code gives a formal description of the information that the adult speaker-hearer needs to be able to use in processing language. Generative grammatical theory sets out to describe the linguistically relevant features and the general properties of the system of rules that are used for relating the physical sound of a spoken message to its semantic meaning. Chomsky's focus is on the obligatory, rule-governed systems constraining how people create the linguistically encoded output form of their ideas and on how people use their knowledge of grammar in decoding the spoken message.

Fundamental to the generative theory of language is the realization that in order to understand a sentence, the hearer of a speech utterance must have the ability to label the string of words in a sentence as to their Noun, Verb, etc. category, and he also must be able to generate a description of the basic syntactic relation between the words of each phrase and clause of the sentence. Thus comprehending a sentence, be it presented orally or in writing, involves the ability to produce a syntactically-labeled bracketing which describes the hierarchy of relations between the string of words at the surface level of the sentence. Only with this knowledge can one construct the phonetic form or the semantic meaning for any given string. On p.29 is drawn a diagram adapted from that in A. Liberman (1970). This diagram outlines the psychologically significant levels in the language code. It reveals the complexity of the linguistic code as well as the hierarchical organization by which the deep-structure semantic relations are mapped via a series of syntactic, phonological, and speech-code rules into the acoustic-output structure received by the perceiver's ears.

An examination of the diagram on p.29 reveals that at the deep-structure level are the base rules for expressing the Noun Phrase and Verb Phrase

relations of the basic ideas that the speaker plans to convey. Chomsky (1965) stresses that it is the deep-structure information that determines the semantic interpretation of the sentence. This is the information that the listener needs to recover in order to comprehend the message. A look at the surface-structure level shows to what degree the form of the three basic deep-structure sentences has been changed by the transformational rules of the grammar. At the next level it is the rules of phonology that assign a phonetic representation in terms of articulatory features to the abstract segments of the surface structure level.

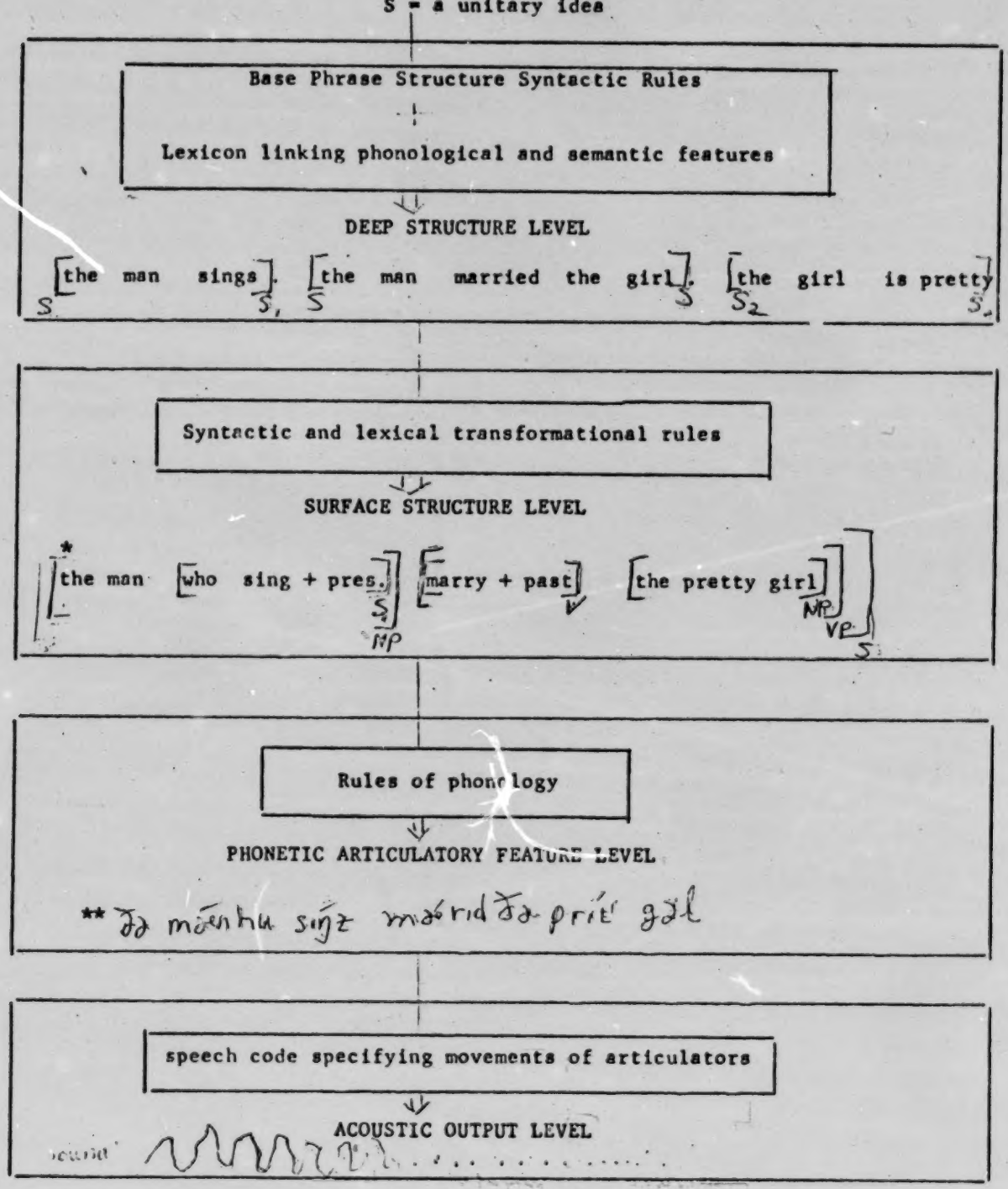
The deep-structure contains the base phrase structure rules which specify the structure of the Noun Phrases and the Verb Phrases of the Sentences of the language. It also specifies a lexicon containing the relevant information about both the phonological structure of the words and the syntactic categories they can fulfill.

Two types of co-occurrence (i.e., context sensitive) selectional restrictions on word usage must be specified. The first set of selectional co-occurrence restrictions requires that either the nouns or the verbs of the lexicon be strictly subcategorized according to the syntactic frames that may co-occur with them in any actual phrase or sentence. Thus, for example, certain verbs like "hit" must always have a complementary object Noun Phrase as part of their Verb Phrase structure while other classes of verbs like "sleep" never can take an object complement in the Verb Phrase.

The second type of selectional rules specify obligatory semantic subcategorization features for these already listed syntactic frames. These rules describe those semantic subcategorizations that function syntactically in that they restrict the choice of lexical items that may be inserted in specific syntactic categories. For example, using "frighten" as the verb

HOW A MESSAGE IS ENCODED FOR SPEECH

(Adapted from A. Liberman 1970)



*The letters represent the abstract underlying feature matrices of the phonological form of the morpheme.

**Each phonetic symbol represents a set of articulatory features to be converted into spoken sound.

of a verb phrase means that the object-noun of the phrase must be an animate one. Thus any speaker of English knows that one can frighten a cat but one cannot frighten sincerity (Chomsky, 1965).

Chomsky's description of the adult's internalized linguistic competence provides one with an explicit description of which syntactic and semantic features are contextually determined and therefore predictable given the selection of any specific lexical item in a sentence. The ability to use this knowledge of the language's selection restrictions reduces the amount of information needed to understand a sentence.

Beside syntactic co-occurrence selection restrictions, there are context-predictable phonological features restricting both the structure of the morphemes of the language and of the junctures between morphemes. Thus when the processor has information on certain features be they phonological, syntactic, or semantic, other features then become predictable from his knowledge of the grammar. It is the ability to use this knowledge of a hierarchy of contextually predictable features that tremendously reduce the amount of information that a person must store in linguistic processes.

MacKay (1967) defines perception as "the organism's adaptive response to redundancy in the pattern of demand and constraint imposed upon it by the field in which it is active" (p. 28); he says that it is this ability to automatically use complex systems of contextual restraints that explains why there is no one-to-one relation between conscious percepts and the features in the input signal. In language decoding tasks, one realizes that the perceiver takes advantage of his knowledge of the hierarchy of linguistically redundant features in his code's system as he processes language input signals.

A look at the surface-structure level in Liberman's diagram shows to what degree the form of the three basic deep structure sentences has been changed by the transformational rules of the grammar. Liberman (1970) emphasizes that in passing from level to level, the number of units and the shape of the segments is changed. Thus there is no invariant ordering of the units from level to level; rather each level represents a successive recoding of the relevant information. At the surface structure level, the "lexical representation is abstract in a very clear sense; it relates to the signal only indirectly, through the medium of the (phonological) rules" (Chomsky and Halle, 1968, p. 12). At the surface level, each morpheme of the sentence is represented as a sequence of discrete segments and each discrete segment is described by a set of distinctive features. In Chapter I it was shown how the speech-production processes result in the acoustic cues for consonants being folded into the formant cues for the vowels, so that at the acoustic level the sets of features for each of the phonemes of a word are no longer separate entities; rather they have been folded into each other in such a way that they are transmitted in units of syllabic size.

The diagram also shows that for any level of representation after the deep structure level, in order to understand the sentence, be it written or spoken, the decoder must bring to the task a knowledge of the deep-structure syntactic relations of the words in each phrase and clause as well as a knowledge of their semantic value. Despite the fact that there is never a conscious categorization of words in a sentence as nouns and verbs or subjects and objects, or agents and actions, nevertheless it is clear that "intricate syntactic and semantic processing...must go on in sentence understanding (Brewer 1972, p. 363).

One can use Liberman's diagram to aid the understanding of what a letter of the alphabet represents in terms of the English orthographic code. In the hierarchical organization of the linguistic system, one finds that, at the surface-structure level, each morpheme is represented by a series of discrete phonological segments. Each of these segments is described by a matrix of distinctive phonetic features. However, before reaching the phonetic-articulatory level, Chomsky and Halle (1968) show that there are complex phonological rules which specify that certain feature changes will be made from the lexical level of representation to the phonetic articulatory level. These changes result because of either the phrasal and clausal structures or the syntactic category of the word (export is pronounced differently depending upon whether it is a noun or a verb), or else the sound changes take place because affixes are added to a root morpheme. For example, the word Egypt is pronounced iy j pt but Egyptian, the derived adjective, is pronounced [ə jipc ə n]. Chomsky and Halle describe the system of rules that underlie these predictable patterns of sound and stress changes. What is important to observe is that the written forms preserve the morphological identity of the stem and of the ending.

Labov (1970) notes that letters are recognized as wholes. In the written representation, one letter tends to correspond to one discrete segment of the lexical representation at the surface structure level; while at the surface structure level in oral speech, these discrete phonemic segments of the lexical unit are described by a matrix of distinctive phonetic features. Chomsky and Halle (1968) find that the English orthographic representation of words "is a near optimal system for the lexical representation" (p. 49). Since the orthography does not represent those sound changes that are predictable by using one's knowledge of English phonological

rules, Chomsky (1970) concludes that the orthographic code "permits the most rapid transition to the semantically significant units" (p. 13). Therefore he finds that questions of phoneme-grapheme correspondence are a "pseudo-issue." However, the reading teacher knows that the problem still remains of how to help children to discover that the individual letters of a word have a complex relation to the sounds of his words. Written words of English can only be pronounced correctly when the child discovers that they represent an encoding of the abstract string of matrices describing the phonological form of morphemes at the surface structure level; thus in order to be read aloud, the child must apply a knowledge of the phonological rules to the written encodings. The child comes to the learning-to-read task knowing a great deal about the syntax of his language and knowing many words and their meanings. What needs to be studied is how abstract is the phonological structure of his lexicon. Chomsky and Halle (1968) observe that maturational factors may effect changes in a child's lexical system. They find some evidence that "children tend to hear more phonetically than adults" (p. 50). Therefore it needs to be investigated whether certain aspects of the English orthographic code represent a more abstract coding than is part of some children's linguistic system.

2. Visual Pattern Matching and Scanning Strategies

Discussing visual processing, Arnheim (1969) emphasizes that an essential part of perception involves cognitive thinking. Eye movement is not random. For example when people look at an object, they actively direct their attention, controlling where they look and which aspects they focus upon. One knows how remote the perception of the shape and size of an object is in relation to the object's projection on the retina. "We unconsciously

correct for faulty vision by using other facts that we know about the real world" (Arnheim 1969, p. 15). Arnheim believes that "active selection is a basic trait of vision, as it is a trait of any other intelligent concern" (p. 20).

Hochberg (1970) is interested in explaining a viewer's flexibility in distributing his focal attention over a visual field. Hochberg compares the skilled reader's text-sampling strategies to the viewer's scene-scanning strategies. He finds that the skilled reader's processes are not "an automatic sequential decoding operation"; rather whenever a person scans either a scene or a written text, the strategy is first to attend to the "major potentially informative points," and then "where small detail is needed...saccades will bring the appropriate regions to the fovea" (p. 76). Hochberg believes that the skilled reader uses the spatial framework of a text for locating the "distal address" of "different shapes" on the page. The reader controls his visual scanning processes by using hypotheses that he keeps forming about the content of the text and about where he can locate the information he needs to confirm his hypotheses. These cognitive decisions about where to position successive fixations on the page are aided by the content extracted from the preceding fixation. This includes information from peripheral vision about the visual length of the words and of the phrases. Thus peripheral vision helps guide the skilled reader's text-scanning strategies.

Hochberg's description of attentional scanning processes focuses on how visual features of the text affect this. Hochberg states that the skilled reader's knowledge of orthographic and syntactic redundancies along with peripheral visual data guide the visual sampling strategies, but he never really explains what he means by knowledge of the spelling system. His emphasis

is on the reader's ability to use distinctive visual features. The reader first finds out about word length and then perhaps a focal glance at the first letter of the word is enough to allow the skilled reader to "recognize" the word in the context. While skilled readers use their knowledge of constraints on English phonological structure to guide their text-sampling strategies, one also must question whether the skilled reader may not also be using his knowledge of the entire hierarchy of linguistic redundancies that constrain the structure and content of any sentence as aids in his visual search.

Like Hochberg, Kolers (1970) was interested in the effect of visual features of the word on word-recognition processes. He concluded that word recognition is not dependent on recognizing each letter because readers can recognize words shown at a distance from the fixation point such that the individual letters are unrecognizable. Furthermore, tachistoscopic studies show that familiar words are more easily recognized than non-familiar words and that words are more easily recognized than letters. Johnson and McClelland's study (1974) showed the importance of the whole word in visual perceptual processing. They showed that it was easier for a subject to decide whether he had seen the word COIN or JOIN, than it was for him to decide whether he had seen the letter C or J. Studying the number of errors that subjects make in naming such letters of Pseudoword strings, Kolers (1970) found that these errors were independent of the position of the letter in the "pseudoword" string, however in reading real words, the first letter is the one most easily recognized. Kolers concludes that this focus on the first letter of the word is due to linguistic factors and not to visual scanning strategies. Kolers concludes that adults use the visual

gestalt of the word's shape to aid them in rapid silent reading. He believes that the adult's word-reading processing involves the gestalt first and then segmentation via linguistic knowledge.

The differences between visual scene-scanning and the visual requirements for reading cause Hochberg (1970) to conclude that the first task of the child who is learning to read is to translate "spatial into temporal order" (p. 77). The child's visual mechanism keeps track of spatial relations, not of the time order of the sequence of visual fixations; yet because the left to right spatial order of the words on a line in the printed text corresponds one-to-one with the temporal sequence of the string of words in the spoken sentence, the beginning reader needs to learn to execute and keep track of small sequential fixations along the line on the page. The child must learn the spatial framework order of the written words and how it relates to the temporal order of the sounds of his spoken words. Hochberg believes that the use of large type helps the child in this first stage of reading since the child needs to focus on each letter of each word to recognize it. Later he will be able to use peripheral visual information on word shape along with his knowledge of orthographic and syntactic redundancies to direct his visual search.

3. Active and Passive Models of Human Perceptual Processes

Broadbent and MacKay propose two different models by which humans determine the features of the input signals relevant for the coordination of their input-output behavior. Broadbent's general theory of human perception (1967) rejects the hypothesis that central processors actively organize the features of the incoming signal. In the 1973 version of his theory of human information processing, Broadbent added to his passive model, a response bias,

i.e., a recognition mechanism which is biased for "particular features which are likely to occur in certain circumstances" (p. 31). He finds that people have "a slacker level" of evidence requirements for recognizing a probable event than they have for recognizing an improbable event. His theory is not clear in what way these biases are incorporated in the actual perceptual processes, but the biases are a way of incorporating into a performance model the effect of past experience, learning, and contextual factors on perception.

Broadbent specifically rejects the concept of an active processor selectively testing incoming stimuli in order to see if they possess evidence confirming hypotheses about what the event is (1973, p. 37). Instead, using his studies of variation in human goal attaining strategies, Broadbent finds that he can describe the possibility of any human act by using the Bayesian theory of statistical probability to describe adjustments in criteria for actual choice.

If Chomsky's description of the hierarchical nature of the linguistic code is correct, then sentence decoding must involve a series of decision operations because higher level information is needed to make lower level decisions. Therefore sentence processing cannot result only from autonomous input-filtering mechanisms. While Broadbent's theory does not seem adequate for describing sentence decoding, it does shed light on much of preattentive pattern recognition processing. Pattern discriminations do seem to be premediated to a large degree by peripheral mechanisms which extract from the input stimulus the features needed by the central processors for recognition (Uttal, 1973) However, Turvey's research also shows that central processes do influence ongoing peripheral processing systems before recognition is completed. Broadbent's model does explain the skilled reader's word recognition

processes in which past experience is shown to reduce the amount of information necessary for recognition of the word as a whole.

In contrast to Broadbent's theory of a biased-passive processor, MacKay (1967) emphasizes that human perception is an active recognition process. He agrees with Broadbent that "any perceptual model of visual or auditory system had better assume the existence of banks of filters in the input to the organizing system, permitting a preliminary extraction of cues to which the internal organizing process has to match itself" (p. 33). But MacKay also has incorporated an analysis by synthesis into his organizing process. MacKay feels the need to add to any perceptual processing model, a meta-organizational process which enables the processor to reset the goals in a way that "what I perceive becomes a datum for my calculation of any action or reaction to which its presence is relevant" (MacKay 1967, p. 26). Thus this meta-organizing mechanism enables people to actively adapt to new inputs. The process of perception involves not a biased averaging schema but rather the individual's ability to modify the internal state of his organizing system if he finds discrepancies between the incoming data and his internal criteria for evaluating the input signals. Fundamental to MacKay's (as to Luria's as shown in Chapter I) human information processing model is the belief that complex analytic and synthesizing operations enable the perceiver to react to specific stimuli even in the first stages of the decoding process.

4. Oral Speech Perception

In discussing theories of speech perception, Neisser (1967), rejects the theory of a simple one-to-one template matching process of perception. The speaker's individual age, sex, dialect, emotional attitudes, rate of

speech etc. all cause too much variation in the acoustic form of an utterance for a processor to match the input signal to stored auditory memories. Neisser also rejects Broadbent's theory of an attentional-biased filter model as being adequate for describing speech perception. Shadowing and other dichotic listening studies with speech input into each ear, show contamination can come from the unattended ear. This implies that the processor has performed some analysis on the input to each ear before turning his focal attention to actually synthesizing the message in the attended ear. In a dichotic listening study, Lackner and Garrett (1974) found that they could disambiguate an ambiguous sentence to which the subject was attending, by putting into the unattended ear a word or phrase that would disambiguate the focal sentence.

Neisser's third theory of speech perception is that of analysis-by-synthesis. Neisser points out that this theory of perception allows for a preliminary operation in which the perceiver must make an analysis of the phrasal segmentation of the input sentences. This information about the major sentential segments is then used for the second stage in the analysis. The listener needs to have this phrasal and other contextual information along with his own expectations, in order to identify the abstract structure underlying the acoustic input cues. Due to the hierarchical structure of a sentence, decoding involves a series of contingent operations.

In their motor theory of speech perception, Stevens and Halle (1967) hypothesize that the listener classifies auditory impressions according to the articulatory-gesture program that would have been used were he to have been the producer of the message. Liberman (1974b) emphasizes that by using production rules for perception via a matching operation, the

listener is able to compensate for variations in speech input due to individuality in speaker's performance. Since the speech encoding process results in any point in the acoustic stream carrying information on the distinctive features belonging to at least two successive phonemes, Liberman (1974b) sees the need to incorporate a motor-matching mechanism into the speech perception process. Without this mechanism, he does not believe it is possible to segment the acoustic stream into the discrete units of the surface structure level. A motor matching process allows the perceiver to identify the phonetic features of the syllables; "the human brain decodes...the acoustic signal in terms of the articulatory maneuvers that were put together to generate the syllable" (P. Lieberman 1973, p. 62).

In arguing for the use of a motoric schema in speech perception, Liberman et al. (1967), Miller (1963), and Stevens and Halle (1967) all emphasize that people have formed special ear-voice linkages which tie together speech perception and production systems. As seen in Chapter I, Luria (1966) shows that motor analyzers are involved in speech perception. In any speech utterance, the speaker is actively listening and monitoring his own speech output. Thus it is not so strange that the speech perception mechanism be linked to a feedback mechanism utilizing the speaker's articulatory-gesture program for producing the phonetic features of speech (Liberman, Cooper, Harris, MacNeilage 1962). Miller (1963) points out that as the infant is uttering a syllable, at the same time he is stimulating himself acoustically and kinesthetically. Thus the young child has developed close links between his articulatory motor percepts and his acoustic percepts. The question that one asks in relation to the learning-to-read process is what is the best way for the child to learn to apply this motor-acoustic perceptual system to the task of processing the visual input stimuli.

It is to be noted that Fant (1967) does question whether one needs to have "active mediation of the motor patterns of speech in speech perception" (p. 114) up to word level. The cochlear's physical constraints on acoustic perception may eliminate the need to use articulatory pattern-matching for recognizing some phonemes, syllables, and words. The ability to speak is not required for understanding speech. Lenneberg (1966) discusses a child who had such a severe articulatory disability from birth that the child never learned to utter an intelligible word; yet the child learned to understand language. Dichotic listening studies, such as that of Lackner and Garrett (1972), show that a word in an unattended ear can affect the processing in the attended ear. Such evidence affirms Fant's belief of separate centers for processing the sound pattern of a word and its motor pattern.

However, Fant does feel that people do have the option of using knowledge of the speech-code motor patterns whenever there are difficulties in processing a message. Furthermore Fant agrees that when processing the higher levels of any speech message, one needs to use a knowledge of linguistic and conceptual constraints. Stevens and Halle (1967) stress that "the perception of speech involves the internal synthesis of patterns according to certain rules and a matching of these internally generated patterns against the pattern under analysis" (p. 88). For them it is thus a fundamental requirement that the perceiver of the input signals know the phonological, syntactic, and semantic rules that have been used by the speaker for "transforming the abstract representation (of the surface structure level) into the articulatory instructions" used for uttering the sentence (p. 101).

Summary

This chapter analyzed the generative theory of the nature of language knowledge in relation to the task of decoding spoken or written sentences. The theory described the linguistic code in terms of the syntactic and lexical co-occurrence rules and the system of operations which constrain the set of possible output sentences of English. A study of the hierarchical organization of the psychologically significant levels in the transformation of deep-structure ideas into the spoken sentence has shown that the writing code is more abstract than the speech code. The writing code does not represent certain sound changes that are predictable according to the adult speaker's phonological rules (Chomsky and Halle 1968). This facilitates the skilled reader's rapid decoding of the written input (Chomsky, 1970).

A review of studies on word and text scanning strategies led to the questioning of the cognitive factors that were guiding the skilled reader's visual recognition processes. Broadbent's biased passive model of information processing was found to give insight into feature extraction by peripheral sensory mechanisms. However it was concluded that the processing of linguistically encoded messages must include serial processing for modifying peripheral parallel processing systems. Turvey (1973) has shown that higher-order factors affect peripheral pattern-recognition processes. Complex analytic and synthesizing operations must be hypothesized in order to explain the recovery by the processor of the deep-structure semantic relations of the lexical constituents in a sentence. This use of higher-order linguistic information may serve to explain the statistical "biasing" that has been observed in speech decoding processes.

Chapter III

SIMILARITIES AND DIFFERENCES IN DECODING STRATEGIES FOR ORAL AND WRITTEN LANGUAGE INPUTS

Introduction

The preceding chapter has discussed two models of human information processing. It has been shown that pattern matching alone cannot explain the complex mental processes necessary for understanding a sentence. Part of sentence processing requires knowledge of the relations of the words in a sentence. While part of the meaning of a sentence depends upon recognizing the lexical words and the grammatical words and affixes as given at the surface structure level, phrase and sentence meaning may also require deeper knowledge of the relations between the surface items. Understanding the two meanings of an ambiguous phrase like "the shooting of the hunters" requires reconstructing the two possible deep structure relations between the surface lexical items. Higher order processing than phrasal segmentation is needed for understanding sentences.

N. Chomsky (1965), Bever (1970), and Cooper (1972) all emphasize that one must carefully distinguish between a theory of the structure of language and perception models. Models of perception question how people use linguistic forms. Perception involves a description of human strategies for understanding (and producing) language. Performance models need to take into account the effect of factors such as attention and memory.

Chomsky (1965) thinks that people may have "stock perceptual strategies" for analyzing phrasal and clausal constructions in oral language processing (p. 14). He notes, for example, that adults are limited in their ability to decode self-embedded sentences such as: "the man whom the boy whom the students recognized invited out is a friend of mine," though they have no trouble understanding "the man whom the boy invited

is my friend." The first sentence requires pencil and paper in order to diagram the underlying structural relation of each of the embedded clauses and their relation to the higher clauses. Chomsky concludes that there is a real human performance limitation on the ability to simultaneously use and reuse the same "stock" syntactic analytical procedure. When Blumenthal (1967) gave subjects such multiple-embedded sentences to listen to, the tendency was to interpret the sentence as if it were composed not of subordinate clauses but of strings of conjoined subjects and conjoined predicates. (It is to be noted that in these sentences there are no semantic reasons restricting any noun from functioning either as the agent or as the receiver of the action of each verb.) Blumenthal found that when people were given such complex embedded sentences, they were unable to discover the deep-structure relations. The tendency was to simplify these complex hierarchically embedded structures by recalling them as less complex sentences composed of conjoined Noun Phrases and Verb Phrases.

In this chapter the focus will be on the similarities and the differences in the perceptual strategies people use for processing oral and written inputs. The first part of the chapter will show similarities in perceptual strategies. It will then question what modality specific cues can signal to the processor the information necessary for comprehension. In the preceding chapter it was shown that because of the individual variability in the acoustic signals, Stevens and Halle (1967), and Liberman (1967) have proposed a motor-matching analysis-by-synthesis process for decoding spoken language. This chapter will explore Halle's conclusion (in Kavanagh and Mattingly, 1972) that due to the more abstract level of encoding in the written text, the skilled reader can operate at a more abstract level, bypassing the motor level of speech decoding processes. However with respect to mental operations by

which the processor recovers the higher level relations of the lexical constituents, Stevens (1972) and Cooper (1972) feel that an analysis by synthesis process may need to be utilized in both reading and spoken language decoding processes.

1. Evidence of Similar Sentence Processing Strategies for Speech and for Written Input Signals

a. Nature of operations in speech perception

Brown (1970) has observed that whenever the goal of a research study is to characterize the clues to the underlying structure and to describe the heuristics by which the processor makes use of these clues, then the same conclusions seem to be reached whether the input is oral speech or written sentences. There are many studies on oral language perception to show how the processor uses knowledge of his language code to process a sentence. Miller and Isard (1963) show the psychological significance of syntactic structure in aiding oral language perceptual tasks. They compared how varying signal-to-noise ratios affects a subject's accuracy in processing normal, anomalous, and ungrammatical sentences. They found that an important factor increasing perceptual accuracy was the perceiver's ability to use his knowledge of syntactic and semantic rules.

Fodor and Bever (1965), Garrett, Bever, Fodor (1966), Bever, Fodor, Garrett (1966) conclude from their studies that the hearer segments the continuous speech-input into its major clausal constituents early in the speech decoding process. They performed a series of experiments in which click noises were imposed on complex sentences. It was found that people tend to hear the clicks as if they were placed near the major syntactic breaks. People locate clicks at clausal boundaries even when there are

no real physical pauses in the acoustic stream as cues. Therefore, it was concluded that the listener himself is actively constructing this segmentation of the input sentence into its major surface constituents. Hierarchical clustering studies test a subject's judgments as to the relative strength of the relations between the words of a sentence. Subjects decide on the relative closeness in triadic comparisons. These studies reveal the psychological reality of the underlying phrasal and clausal hierarchy of the sentence's linguistic structures (Levelt 1970; Zurif, Caramazza, Myerson 1972).

Other language perception studies agree with the click study evidence showing that early in the listener's decoding process, the clausal and phrasal structures of the input material are located. In close shadowing studies, the subject simultaneously receives a different speech message into each ear and his task is to attend to one of these messages, repeating it as he hears it. Shadowing latency is affected by the grammatical structure of the material; the error rate doubles when the input is a random string of words rather than a normal sentence.

Jarvella (1971) studied adult's verbal recall abilities in order to understand the effect of short and long term memory coding storage systems in sentence processing. He found that people can hold the last clause that they have just heard in a verbatim form, but that the sentences heard previous to this final clause are transformed into a form enabling the perceiver only to paraphrase their contents; thus these earlier-heard sentences are no longer in a form which allows the subject to generate a verbatim recall. They have been recoded into another form. Whatever is the nature of this information in long-term storage, it does not allow for a verbatim

recall of input. Thus the specific lexical items and the structural relations in the input-sentence are not part of the long-term storage encodings.

b. Hypotheses about alternative heuristic approaches in speech decoding acts

Bever (1970) and Johnson-Laird (1970) have questioned the nature of the speech perception operations by which the sentence is understood. Johnson-Laird analyzed the cues in the surface structure string that may be aiding the processor to perform a surface parsing of the input sentence. He agrees with Bever that the Garrett, Bever, Fodor (1966) click experiment shows that speech perceptual mechanisms are actively involved in the grammatical analysis of the surface string of words. For Johnson-Laird, grammatical markers may be important cues facilitating the construction of a surface parsing of the spoken sentence. He notes that the definite article "the" informs the processor that a Noun Phrase is to follow, and English speakers know that usually a Noun Phrase ends with the Noun. Johnson-Laird believes that grammatical words and affixes are used by the processor to aid him in locating content words and to predict what structure may follow; thus people are actively performing higher-order processing of the sentence while the sentence is still being uttered, an analysis by-synthesis procedure. Johnson-Laird stresses that the meaning of a sentence must be mediated by the recovery of the deep structure relation of the constituents and to do this the processor may be making use both of his knowledge of lexical co-occurrence syntactic restrictions and also his knowledge of how specific transformational operations result in the use of specific grammatical words in the surface sentence (such as some form of the verb "be" + past tense main Verb and "by" in a Passive sentence). Thus he finds

that grammatical words and affixes aid a surface parsing mechanism and also in recognizing the deeper structural relations.

Bever (1970) describes a series of strategies that his click experiments lead him to conclude people use in decoding speech messages. Bever believes that adults possess behavioral strategies which enable them to first segment the input sentence into at least those deep structure sentences whose "order is literally reflected in the surface structure" (p. 291). In language processing the first decoding strategy is to make hypotheses about the internal structure of the major clause. An early step in perceptual organization seems to be to segment the string of words in the input into a constituent ...Noun Verb (Noun)...series which could have the logical internal relation of Actor Action Object ...Modifier. Then unless a subordinate conjunction or else a formative marker (such as an -ing on the verb or a preposition) marks subordinate relations between these sequential lexical items, the semantic strategy is to label the first Noun Verb (Noun) (Modifier) sequence as the main clause of the sentence and to assign to them this Actor, Action Object Modifier relation.

Once the sentence has been segmented into its major clause and once some lexical constituents have been identified, Bever, like Johnson-Laird, believes that the decoder may then make use of his knowledge of lexical co-occurrence constraints in forming hypotheses about the deep structure internal relations of the rest of the sentence. Thus heuristic strategies do not require the processor to operate with all the syntactic rules by which the sentence was generated. The listener knows that a verb like "see" can take a complex as well as a simple noun phrase complement. Therefore, he will process a sentence with the verb "see" with different syntactic expectations from those for a sentence whose verb is "hit," since "hit"

takes only simple complements. Thus as they process a sentence, people utilize their knowledge of syntactic structures that are possible for specific lexical items.

Bever proposes a third perceptual strategy, a semantic one, in which the processor makes hypotheses about the functional relations between lexical constituents on the basis of semantic plausibility. He believes that this use of semantically plausible relations between lexical constituents can "guide the interpretation of sentences, independently of and in parallel with perceptual processing of the syntactic structure" (p. 297). It would be interesting to use Bever's proposed series of speech perception operations for analyzing the errors that Thorndike's children (1917) made when they wrote answers to questions on the paragraphs that they had just read.

While Bever used click experiments to help him in understanding the nature of the perceptual operations used in speech decoding. Goldman-Eisler (1972) studied perceptual segmentation procedures by analyzing performance in simultaneous translation situations. Her study caused her to agree with Bever and Johnson-Laird that in any speech decoding act, first the sentential input must be segmented into major syntactic constituents. She believes that this segmenting process "is part of the perception of the input" (p. 139). The input message must be processed in such a way that the translator can recover the lexical constituents and the semantically relevant syntactic relations. She believes that the analysis by synthesis is guided by "context and expectation." Once segmented, the input is decoded and held in active verbal memory in a form suitable for transmission in a second language. Goldman-Eisler, like Jarvella, describes a third stage in which the decoded message is recoded into a form suitable either for long-term storage or for recall and paraphrasing.

Goldman-Eisler believes that it is the decoding of the input for comprehension that requires the active attention of the process or she shows that the translator is actively performing a structural analysis while the sentence is still being received, and that context and expectations aid the analysis-by-synthesis decoding of the segmented input. The need for information about subject and predicate determine the minimum input-output lag. She found that the translator's minimum requirements before beginning the translation was to hear the Noun Phrase (the sentence's subject) nd at least the Verb of the Verb Phrase. Usually this meant a five-word delay between input and translation. However Goldman-Eisler says that predication was "a crucial part of the information required" (p. 131) before the translator began the oral translation. In terms of memory load, she notes that the end of the clause is less of a load on memory than is the beginning of the sentence. This is as would be expected, since it is the beginning of a sentence that contains the maximum amount of new information, for the start of a sentence is usually the point of maximum uncertainty as to the semantic content.

In processing a speech message, the listener first perceives the major structural constituents of each phrase; the question is whether prosodic cues may aid this segmenting. In speech-signals, prosodic features are acoustic cues that can inform the listener about the surface structure bracketing. Prosodic features are those features "not inherent in the phoneme" segments; prosodic features "require reference to a 'chain' of syllables over a time sequence," (Jakobson and Halle 1962, p. 479) and can be varied on one syllable or over a series of syllables. The vowels of the utterance are the usual carriers of the prosodic cues. The listener's decisions about prosodic information are based not on the absolute values of

the voice-pitch, or the voice-loudness, or the duration of the sound, but rather on changes and deviations from some speaker (and language specific) expected norm value. Decoding prosodic features requires that the listener be able to hold the sounds in storage for short periods of time since decisions are context dependent.

P. Lieberman (1967) shows that both the subject's knowledge of the grammar of the language and knowledge of the articulatory movements used in speaking, influence intonation percepts. For example, in making decisions about the contour of a breath-group, especially if the main stress is early in the breath group, the listener will decide that the contour is rising if the terminal frequency merely falls less than it would fall naturally at the end of a breath group. This slightly-raised terminal frequency is a sufficient cue to be perceived as a distinctive feature.

The simple declarative sentence in English has a breath-contour that falls off at the end. Lieberman calls this an unmarked breath-group. Simple wh-questions and imperative sentences also use this unmarked breath intonation contour. The yes-no question has a marked intonation in which the natural fall at the end of the breath-group is not allowed to occur. A speaker can transform any declarative sentence into a question by using this marked intonation contour. The speaker also uses this marked intonation at the end of each phrase that is followed by a conjunction so that the listener is informed that the sentence is not yet complete.

Whenever a speaker places contrastive stress on a lexical item, he affects the meaning of the sentence. For example, by placing special emphasis on the word "Joe" in"Joe ate the soup," the speaker is denying that it was anyone other than Joe who did this act. Similarly if the speaker placed a special stress in "ate" the listener realizes that it is

the act of eating (versus "spilling" etc.) that is being asserted. Emphasizing "soup" means the speaker denies that Joe ate anything else (examples are from Lieberman 1967).

P. Lieberman (1967) notes that Chomsky and Miller have concluded that a speaker cannot use any special breath-group contrast to disambiguate the ambiguous deep structure syntactic relations of sentences like "flying saucers can be dangerous." However, suprasegmental features do convey to the listener information about the speaker's emotions. Lieberman notes that speakers can express extreme emotions by either raising or else by lowering the range of their fundamental speech frequency. Another way to express emotional attitude is by extending the normal length of one's breath group or by making special use of pauses.

Lieberman (1967) notes that stress placement interacts with the breath group's fundamental frequency contour to influence contour perceptions. In Chomsky and Halle (1968) the English phonological rules for placement of stress on words and on phrases are described. They show that syntactic and phonological factors determine stress placement decisions. As for stress perception, Lehiste (1970) emphasizes that it is different from the perception of loudness. She notes that Jones (1940) concluded that "stress refers only to the degree of force of the utterance; it is independent of length and intonation although it may be combined with these" (p. 119). Perceptually the receiver of the spoken message searches for the relative prominence of certain syllables. Relative changes in length, pitch, and timbre are all cues to prominence. Lehiste observes that Jones anticipated the motor theory of speech perception in stating that "stress perception involves a knowledge of the language in which the utterance is spoken" (p. 119). Quoting an experiment of his done in 1965, Lieberman (1967) shows that even

competent linguists use knowledge of higher order units in making decisions about stress patterns. Lieberman (1965) gave his subjects a series of sentences consisting of the same words and similar breath contours but having different fundamental frequency ranges. The sentences were still perceived as having the same pitch contours.

With reference to the perception of word-level stress, Lehiste and Lieberman agree that this is influenced by the speaker's linguistic knowledge. The speaker knows which syllables on a word may carry stress. Lehiste states that word level stress "is in a very real sense an abstract quality" (p. 119). In order to perceive word-stress placement, the listener seems to also require some knowledge of the word. Studying the effect of variations of fundamental and terminal frequencies on perception, Studdert-Kennedy and Hadding (1973) concluded that "the auditory level is not independent of higher levels but is an integral part of the process by which we construct our perceptions of spoken language" (p. 312).

c. Nature of perceptual operations in decoding written texts

Studies on a reader's eye-voice separation give evidence of the effect of grammatical structure on the reading process. These studies measure how much the reader's voice lags behind the position of his eye on the printed page. They show that the skilled reader's information searching processes are affected by the syntactic structure of the sentence. Reviewing Quantz's eye-voice separation studies (1897), Huey (1908) concludes that eye-voice span is affected by the reader's familiarity with the contents of the text; the span can shrink to zero when the reader tries to read an unfamiliar word. Just as Goldman-Eisler found that her simultaneous translation's must monitor, store, and then encode for transmission the

incoming signal, so too eye-voice-span studies show that the skilled reader's oral reading lags behind the input his eye is receiving. Huey says that the full inner utterance 'hangs fire' "...behind the eye until there are present enough visual and motor data to suggest the total meaning" (p. 147). Only then does the oral reading commence.

Levin and Turner (1966) tested subjects from second grade to college level by giving them to read aloud strings of words, and active and passive sentences composed of phrases 2,3, and 4 words long. They found that by 4th grade, the children's eye-voice span was "elastic" depending upon the phrase structure. Levin and Kaplan (1970) showed that deep structure relations, too, will affect the reading process. They found adults have a larger eye-voice lag for passive than for active sentences. They concluded that the reader actively searches passive sentences looking for the "by-phrase." The reader needs to know the deep structure subject of the action before he reads the sentence aloud. Thus the eye-voice lag measures sentence decoding processes in relation to deep structures.

Quantz's study showed that the skilled reader averaged a lag of 5 words behind his eye position, with the biggest lag at the start of the sentence. This data recalls the data in Goldman-Eisler's study. There seem to be similar decoding processing factors affecting the number of words between what a skilled reader is focusing his eyes on and what he is ready to read aloud and the word lag Goldman-Eisler found for her simultaneous translators. The implication is that the processor in each case must receive a minimum amount of input and perform similar mental analytic operations before he comprehends enough of the input to allow him to start to recode for oral transmission.

Kolers (1970) reports on a series of experiments that indicate that as the reader processes a written sentence, he is actively forming and checking hypotheses about the clausal structures and the meaning of the text. Kolers found when he gave his subjects geometrically transformed texts (letters and whole lines were rotated), that the oral reading errors most likely to be unconsciously corrected were those errors inconsistent syntactically or semantically with the text that followed. When Kolers asked bilingual subjects to read a passage that was written primarily in one language, he found that skilled bilingual readers ignore an occasional substitution of a word from their second language. These interchanges of languages did not affect comprehension. Kolers finds this to be evidence that word reading can go directly from print to semantic meaning.

It is interesting to note that Kolers found that when his bilingual subjects read aloud passages in which he had mixed phrases from the two languages, error changes of the type translating "porte" to "door" tended to occur at the breaks between the two language inputs. Thus a reader would say the English word (even though the actual printed noun was the French version) in anticipation of the coming change from French to English. Kolers also found the reverse effect so that the reader would read changes in the first word of the second language back into the language of the part of the preceding text. His subjects did best when the switches were at syntactic boundaries (Menyuk, personal communication). This, too, shows that in reading, the processor is operating with higher-order units.

Eye-voice span measures allow one to distinguish between "good" (fast) and "poor" (slow) readers. Quantz found a close correlation between rapid rate in silent reading and large eye-voice span (Huey 1908). Miller (1951)

notes that Fairbanks (1937) found that good readers differ from poor readers in that the good (fast) readers tend to have a larger eye-voice span. Fairbanks had also observed that when the text was difficult for a good reader, then the eye-voice span can shrink to zero. This implies that a good reader may be able to use alternative reading strategies depending upon the complexity of the text. Levin and Turner (1966) show that readers who are slow in reading lists of words will also have a shorter eye-voice span than do faster readers. Levin and Turner concluded that the slow reader's eye-voice span is not "elastic." They believe that the slow readers are less able to utilize knowledge of sentence redundancies as an aid in forming expectancies about the text's content. However, Brown (1970) notes that Weber (1970) found that even first grader's oral reading errors show that the children are applying their knowledge of grammar to the reading task.

One can speculate as to whether there may be a cause and effect relation between speed of reading and size of eye-voice span. Elkonin (1973) believes that it is the speed of central processes rather than the speed of eye movements that controls the speed of reading. Weber's evidence shows that even when reading involves a recognition process of scanning unit by unit from left to right, her first graders were applying a knowledge of sentence structure to the reading task. Failure to utilize knowledge of syntactic and semantic contextual constraints does not seem to be an adequate explanation of why poor readers read poorly. It may be descriptively correct without being causal. Eye-voice studies seem to show that two factors may be affecting an individual's reading process. The first is the amount of actual visual input per fixation and the second is the rate at which a subject can process this input. Developmental factors not

grammatical ones seem to affect fixation duration and the span of a fixation. Smith (1971) quotes Taylor, Frekenpohl and Pettee (1960) who show that by fourth grade the maximum rate of fixations per second has been reached. Smith hypothesizes that slow readers may be limited in the use that they can make of peripheral visual information. In Kavanagh (1970) Morton states that his 1964 study using sentences of different approximations to English showed no variation in the duration of his subject's eye fixations (200 ms.). With regard to rate of central processes, Turvey's tachistoscopic studies (1973) show that normal adult readers differ only in central processing rates and not in peripheral processing rates. Therefore, differences in the individual adult's word recognition rates will result because of differences in central processing rates. It would be interesting to use Turvey's tests to compare good (fast) and poor (slow) readers of different age levels in order to question whether they do differ only in central visual processing rates.

2. Form Function Differences Between the Spoken Language Code and the Orthographic Code

a. Visual cues aid in sentence segmentation

The written text, like the speech input, requires that the processor actively organize the sentences by performing an analysis-by-synthesis structural analysis while the sentence is being received. There are specific visual cues that aid this process. In the written form, each word is a distinct visual entity. Grammatical words and affixes are as visible as are lexical items. As distinct from the spoken input, no stress reduction affects the relative prominence of the words of the written text. Each new written sentence begins with a capital letter and ends with a mark of

punctuation. Special punctuation marks are used to mark interrogatives and imperatives as distinct from declarative sentences. Lieberman (1967) notes that the written code's use of colons and semicolons to separate subordinate and coordinate clauses serves as an aid for disambiguating certain derived structures.

However the writing code does not express much of the information that suprasegmental features convey in the acoustic signal. The written code has no way to mark contrastive stress. The reader can only learn of the speaker's age, sex, state of health or of his emotional attitude if it is explicitly stated in the written text. This lack of semantic information conveyed by prosodic factors means that the reader must rely more on his use of linguistic knowledge for decoding the written message.

b. Word shape as an aid in word recognition processes

While the listener must segment the continuous acoustic stream into its lexical constituents, words are separate entities on the printed page. Discussing experiments on studying adult's word recognition abilities when given brief exposures, Morton (1964) states that word-shape confusion explained some errors made by his subjects. Morton found again that word shape was a factor affecting word-recognition in an experiment he performed in which subjects read aloud strings of words of different orders of approximation to acceptable English sentences. Morton notes that given "her toe touched her head and figures," subjects would err by reading it as "her toe touched her head and fingers"; given "I heart," it could be read as "I hurt." Such changes led Morton to conclude that the reading process involved the use of visual word shape information as well as syntactic and semantic expectations.

In his review of word recognition studies, Neisser (1967) gives several reasons why adult word recognition does not seem to be a letter by letter process. People are not aware of all the letters of a word. Pillsbury (1897) showed that subjects will not notice the typographical error in FOYEVER, and will read it as FOREVER. They focus on the overall word shape without seeing each letter. The different letter heights in type using lower-case letters aids word recognition, so it is easier to read a text in lower-case letters than one in all upper-case letters. Hochberg (1970) believes that word length may be a peripheral visual input cue aiding a skilled reader's text scanning strategies. Kolers (1970) finds that a word's visual shape is an important clue facilitating recognition. He believes that words are perceived as wholes by skilled readers. Kolers' word and pseudo-word tachistoscopic recognition studies lead him to state that the beginning of the word conveys more information than the later part. Kolers concludes that the reader first uses the gestalt word-shape cue and then performs necessary segmentation operations.

c. Visual memory and the orthographic code

Paivio (1971) has studied the nature of people's visual memory storage system. He finds that people have a visual image storage and verbal storage system. The written word is a speech symbol and as such requires the linguistic code for decoding it. However, readers can also generate visual images of letters and words, so reading involves the visual storage system too. One becomes aware of the reality of the visual storage system when one considers the adult reader's ability to notice misspellings. Since Pillsbury's studies (1897) it has been known that it is difficult for the readers of a text to notice typographical errors. One also knows that the

written code disambiguates many homonyms, encoding words like right and rite distinctively. When the typographical error consists of homonym substitutions, then the typographical errors are noticed. Despite the fact that the sounds of the words are preserved, the sentence's meaning is destroyed. LaBerge (1972) gives the following sentence: "the buoy and the none tolled hymn they had scene and herd a pear of bear feed in the haul" to show that the skilled reader has learned to expect a specific visual representation for each homonym. Thus a specific part of the adult's reading competence includes this knowledge about the arbitrary visual representation that the orthography uses in writing certain morphemes. Although the wrong spelling for a homonym can give the correct letter-sound resultant, the reader is blocked from giving the sentence a semantic meaning. Reading is for meaning as Thorndike has taught.

d. The orthographic code preserves morphological identity

Chapters I and II have shown certain fundamental differences between speech and written language inputs. The diagram on p.29 shows that the sounds of a speech utterance result from the application of language-specific phonological rules to the abstract representations of the morphemes of the surface-structure level. At the surface-structure level, each lexical item is represented by a string of matrices, and each of the matrices is the set of distinctive features necessary for distinguishing each phoneme of the morpheme. Liberman's work (1970, 1974a and b) has shown that speech articulating motor movements result in a recoding of the sets of features of the phonetic level into syllabic-sized units. Thus the syllable is the unit of message transmission in oral speech messages. In contrast, the writing code tends to represent each matrix of the lexical representation

at the surface structure level by one letter (Chomsky and Halle 1968). Chomsky (1970) states that one can understand what letters represent if it is realized that "letters correspond closely to segments of the underlying lexical representations, and the rules that relate these segments to sound are the phonological rules which are part of the system for producing and understanding ordinary speech" (p. 15).

The writing system thus encodes language at a much more abstract level than does the spoken system. Since the two systems represent structurally different levels in the hierarchical organization of the linguistic code of English, the linguistic content of the two language signal systems differs. When Shankweiler and I. Liberman (1972) studied the major barriers to word reading for beginning readers, they found that error rate in vowel reading correlated with the number of possible alternative orthographic representations for the sound. Halle (1972) notes that the orthographic code has inconsistencies in digraph usage. Shankweiler and Liberman also questioned whether phonetic confusions may be a factor and they plan to test for this. The alphabet provides only five letters to represent all the vowel sounds. The letters of the words represent the phonological and not the phonetic level. A tense vowel is represented by the letter "a" which phonetically is realized as the sound /ey/ while the lax sound of this letter is /æ/ or /a/; the tense vowel represented by the letter "e" will have the sound /iy/ yet when the letter represents the lax phoneme, the sound is /ɛ/; and the tense phoneme represented by the letter "i" is phonetically realized by the sound /ay/ while the lax phoneme phonetically is /ɪ/. Thus in learning to read, some children may also be learning to make much more abstract generalizations about their language system.

Earlier in this chapter it was shown that while a reader or a listener is receiving a message, he is actively decoding the sentence by using his knowledge of higher-order syntactic and semantic linguistic constraints. Morton (1964) studied the errors that adults made when they read aloud eight different lines of print, each of which had a different degree of syntactic and semantic sentential cohesiveness. Morton found that the errors that his subjects made were ones that tended to change the text into a more acceptable syntactic and semantic form. One cause of errors involved suffix alterations. Morton found that subjects were analyzing lexical items into their root and inflectional ending. Subjects would maintain the base of the word but they would change an inflection to another part of speech or else use another inflection to get the same part of speech. Verb number tended to be changed to agree with the preceding noun. Thus "legs was" was changed tp "legs were". Morton's study shows that the reader is actively using his knowledge of higher-order linguistic constraints to aid the segmenting of words into their morphemic segments. Gibson and Guinet (1971) tested children's and adults' ability to recognize words under brief exposure. They showed that verb inflectional endings were perceived as units by third grade children.

Chomsky and Halle (1968) describe the system of phonological rules that adults use for relating the phonological structure of the lexical items of a sentence as given at the surface structure level to the phonetic representation. They observe that the written code tends to maintain (up to certain irregularities) the morphological identity of the lexical items. They also note that etymological origin of certain words is preserved in the orthographic code. For example, Greek words tend to represent Greek spelling; thus the [k] sound is represented by "ch" letters in words like "choir,"

"Christmas"; the /f/ sound by "ph" in sophomore," "pharmacy." While the vowel representation does contain certain inconsistencies, Chomsky and Halle (1968) feel that the orthography is "near optimal" for representing the lexical level of English (p. 49). Because it preserves morpheme identity, the orthographic code facilitates the semantic processing of the written text. However, in order for a reader to be able to read aloud the written text, he must apply the system of English phonological rules to the written representation to derive the phonetic form. Chomsky and Halle (1968) describe the complex phonological rules that an adult speaker has internalized for making stress placement, vowel reduction, and word and morpheme boundary phonetic changes on the abstract lexical representation.

The orthographic code preserves morphological identity; it does not represent certain phonetic variations that are predictable. The skilled reader has learned specific morpheme visual representations. For example, the letters "-ed" represent the concept Past Tense on regular verbs. One writes "tapped," "tabbed," and "patted" yet the final sounds are /-t/, /-d/, and /-əd/ respectively. Klima (1972) notes that comparing the spelling of the word "apt" with the spelling of "tapped," shows that the orthographic system does represent sound forms within a morpheme.

In order that a reader of an English text be able to pronounce the tense vowel -- lax vowel alternations of the "sane"-"sanity," or "serene"-"serenity," or "divine"-"divinity" type of pairs of words, the reader must use his knowledge of English phonological rules. In each of these pairs of adjective-nouns the writing code uses one vowel-letter in the root morpheme to represent two sounds which are phonetically different. The letter "a" of the first pair of words represents the sounds /ey/ and /ae/, while the

letter "e" represents in the second pair of words the sounds /iy/ and /e/ while the letter "i" in the last pair represents the sounds /ay/ and /i/. As Chomsky and Halle (1968) show, the writing code requires that the reader recognize relations which are deep and systematically predictable, relations which are part of the English adult's oral language system.

With regard to the question as to whether or not one can actually bypass any sound representation in reading, Brown (1970) felt that despite the fact that Bower (1970) argues against the need to use any form of sound representation, Brown felt that he was reading Bower's paper "in Bower's familiar Scots accent and that seemed quite a thing for the eye alone to have accomplished" (p. 178). Conrad (1972) and Brewer (1972) believe that even in silent reading the reader needs to use the phonological code for finding the word's meaning. They cite as evidence Conrad (1964) and Baddeley (1971). This research showed that when subjects are given tachistoscopically presented letters, the letters are coded and stored in memory not in their visual shape but according to the letter-name. Subjects' recall confusions show that errors result because of similarities in the acoustic form of the letter-names rather than because of similarities in the visual shapes of the letters. Liberman (in Kavanagh 1970) quotes an experiment of Wickelgren's (1967), which shows that distinctive features affect short term memory errors; Liberman believes that "print is recoded quickly into auditory (though not necessarily articulatory) parameters" (p. 125).

Brewer (1972), Brown (1970), and Conrad (1972) along with Chomsky (1970) all reject reading models such as that of Gough (1972) which postulate only a letter-by-letter sound mapping; they reason that higher-order processes are used early in the text decoding process. They also reject a model of only

a word-to-meaning mapping (Brewer, p. 363). Brewer rejects the latter because while work with deaf children show that such an operation is possible, he also stresses that adult readers can pronounce a written word that they have never seen before. Kavanagh (1968), too, emphasizes that adult readers have alternative reading strategies; he notes that subvocalization is available whenever the text is difficult to decode.

R. Brown (1970) states that "reading could involve auditory transformation without being letter-by-letter for the reader might utilize some parts or attributes of the total printed word as an address for the auditory representation" (p. 178). Thus the reader does not have to explicitly identify all the letters in the word to have enough information to recognize a known word. In their "tip-of-the-tongue" study, Brown and McNeill (1966) showed that when they gave a subject the meaning of a word, if the subject had trouble recalling the names of the word, he might still know the number of syllables, the first letter(s) of the word, and where the primary stress was. Thus long term lexical storage seems to be organized both in terms of semantic markers and in terms of the phonological structure of the word.

Brown's work also makes sense in terms of information processing theories. The start of the word, like the start of a sentence, is the point of maximum uncertainty. Therefore at the start of the word there is maximum variance, so that the first observation will convey to the reader a lot of information because there are the greatest number of possible alternatives at this point. As the reader progresses from left to right, the processor becomes less ignorant so that each successive observation would add less information because the variance is smaller and smaller. The

end of the words is where derivational and grammatical affixes all placed; so once again new information is possible here. Brown believes that the first letters and the final ones like the initial and final sounds of a word may be important clues to the perceiver for finding the "semantic entry" of the word.

Brewer (1972) concludes that the skilled reader may have alternative word reading pathways. Homophones like "chute" and "shoot" show him that the reader does rely on visual information in retrieving word meaning. However, in sentence reading, it is important to realize the need for incorporating higher-order linguistic knowledge in the decoding processes. Mattingly's (1972) description of the reading process as "a deliberately acquired, language-based skill, dependent upon the speaker-hearer's awareness of certain aspects of primary linguistic activity" (p. 145) sums up the theories presented in this paper.

Summary

This chapter has focused on the similarities and the differences in oral speech code and the orthographic code, as well as on the heuristics that the processor has for making use of these clues. It was shown that the written text and the speech input require that the processor actively organize the sentence by performing an analysis-by-synthesis operation while the sentence is being received. The reader of a sentence like the receiver of a spoken message is actively making hypotheses about the major clause constituents. Grammatical markers may be one clue aiding recovery of deep structure relations; knowledge of lexical co-occurrence restrictions also aids this process. In speech, intonation contour may aid the listener in this initial segmenting of the input. The written form segments the sentence

visually into words and the sentence structure, but much of the information provided by suprasegmentals is not automatically encoded in the written form.

The final section of this chapter discussed the differences in the linguistic content of the two coding systems. While speech sounds are classifiable by subsets of acoutsic-articulatory features, the visual shape of letters does not represent the systematicity of the speech sound's structure. The orthographic code is more abstract than the speech code. It represents the phonological level of the lexical items and not the phonetic realization. Thus the orthography preserves morphemic identity and this facilitates semantic interpretation. It was concluded that the skilled reader may have alternative word reading processes so that the phonetic form of the representation may be bypassed in his silent reading.

CONCLUSION

If the skilled reading process involves, early in the decoding process, the active application of knowledge of higher-order linguistic constraints, and if the orthographic code as distinct from the speech signaling system, preserves morphemic identity, can one use this information to help in the understanding of the nature of the task of teaching reading?

While in silent reading the skilled reader may be able to bypass a phonetic representation, this ability implies that the reader has already established systematic relations between written representations and his oral language code. Oral language perception is based on the audio-motor linkages established early in life. Learning how to read may need much vocalization to relate visual to oral language competence. The fact that subvocalization can help in the understanding of a difficult written text shows that the oral-acoustic language system can aid the skilled reader's processes. A reader is also able to construct a phonetic representation for a word he has never seen before. Thus a part of knowing how to read may involve the ability to use alternative strategies in processing a written text.

A child approaches the learning to read task possessing his central motor-acoustic language system, which enables him to construct a semantic meaning from the syllabic-sized units of the speech input signals. Weber (1970) shows that from the start the beginning reader attempts to apply his knowledge of syntactic structure to the task of decoding a written sentence. However, for some children, there is great difficulty in becoming aware of the individual phonetic segments that are folded into the syllabic units of the spoken syllables of speech. Also the abstract level of

representation in the written system requires that the child become aware of the complex rules relating the spoken form of words to their abstract phonological forms. There is some evidence that certain aspects of children's phonological system may still be developing at the time when they are beginning to read (Berko 1961, Read 1970, Zhenova 1973). Cazden (1973) notes that there are also developmental changes in children's ability to consciously attend to the linguistic structure of their words and phrases. There may be developmental factors affecting different children's linguistic systems.

Learning to read means discovering the similarities and the differences in the linguistic content of the oral language and the orthographic codes. As the child does this, he is developing cortical linkages between the visual signals of the written text and his central language system. Chomsky (1970) says that in learning to read the child needs to learn to apply to the written text the system of rules that are part of the speaker's "unconscious linguistic equipment" (p. 16). For the teacher of reading, it is important to realize that the written text is at this more abstract level; written and spoken sentences contain different linguistic levels of information. Therefore, as Mattingly (1972) emphasizes, reading and listening are not directly analogous processes.

The morphemic level of representation may enable the skilled reader in silent reading to bypass a phonetic representation. However, the fact that much of the information transmitted by the intonation of the spoken sentence has no representation in the written text means that the reader must rely more on grammatical markers for extracting the deep relations between the lexical constituents of a sentence. Thorndike's study (1917) showed to what degree these grammatical cues must be correctly understood if the reader is to be able to extract meaning from complex sentences.

The ability to read is a skill that needs to be taught. Unlike the spoken language, an organism will not naturally acquire the reading skill as he matures. Mastery of the skill of reading also requires much practice. Both Huey (1908) and Cooper (1972) conclude that learning to read in certain ways may be analogous to the mastery of a new motoric skill. However the orthographic code is based on the oral language's linguistic system. In reading the ability to perform lexical search independent of context and the ability to utilize higher order structures in the reading process is slowly mastered. Turvey (1973) showed that with experience his adults improved in the rate at which they could recognize briefly exposed tachistoscopic letters. Thus central processing rate can improve with experience. Turvey also found that individuals differ in their central processing abilities, implying innate natural factors may affect individual reading central rate processes.

BIBLIOGRAPHY

Abrams, S.G. and Zuber, B., "Some Temporal Characteristics of Information Processing During Reading," Reading Research Quarterly, Vol. VIII, 1972, pp. 40-57.

Abramson, A. and Lisker, I., "Discrimination Along the Voicing Continuum," Proceeding of 6th Int. Congress of Phonetic Sciences, Prague, 1967, pp. 569-573.

Arnheim, R. Visual Thinking, University of California Press, 1969.

Athey, I. "Synthesis of Papers on Language Development and Reading," Reading Research Quarterly, Fall 1971.

Atkinson, R. and Shiffrin, R., "The Control of Short-Term Memory," Scientific American, August 1971.

Attneave, A. "Criteria for a Theory of Form Perception," In W. Dunn (Ed.), Models for the Perception of Speech and Visual Form, M.I.T. Press, 1967.

Baddeley, A.D. "Semantic and Acoustic Similarity in Short-Term Memory," Nature, December 12, 1964, #4963, pp. 1116-1117.

Bakker, D. Temporal Order in Disturbed Reading, Rotterdam University, 1972.

Baron, J. "Phonemic Stage is Not Necessary for Reading," Quart. J. Exp. Psych. 1973, #25, pp. 241-246.

Berko, J. "The Child's Learning of English Morphology," In Saporta (Ed.), Psycholinguistics, Holt, Rinehart and Winston, 1961.

Bever, T. "The Cognitive Basis for Linguistic Structures," In J. Hayes (Ed.), Cognition and the Development of Language, Wiley and Sons, 1970.

Bever, T. and Bower, T. "Visual-Visual Information Processing," In Reading Project Literacy, 1966.

Bever, T., Fodor, J., Weksel, W. "Is Linguistics Empirical?" In Jakobvits and Miron (Eds.), Readings in the Psychology of Language, Prentice Hall, 1967.

Bever, T., Fodor, J., Garrett, M. "A Formal Limitation on Association," In T. Dixon and D. Horton (Eds.), Verbal Behavior and General Behavior Theory, Prentice Hall, 1968.

Bever, T. and Langendoen, D. "A Dynamic Model of Evolution of Language," Linguistic Inquiry, #4, Fall 1971.

Biemiller, A. "Development of Use of Graphic and Contextual Information as Children Learn to Read," Reading Research Quarterly, Fall 1970.

Blumenthal, A. and Boakes, R., "Prompted Recall of Sentences," Journal of Verbal Learning and Verbal Behavior, #6, 1967, pp. 674-676.

Boomer, D. and Dittman, A., "Hesitation Pauses and Juncture Pauses in Speech," Language and Speech, 1962, pp. 215-220.

Bower, T. "Reading by Eye," in Levin and Williams (Eds.), Basic Studies in Reading, Basic Books, 1970.

Brewer, W. "Is Reading a Letter-by-Letter Process?" In Kavanagh and Mattingly (Eds.), Language by Ear and by Eye, M.I.T. Press, 1972.

Brittain, Mary. "Inflectional Performance and Early Reading Achievement," Reading Research Quarterly, Vol. 1, 1970, pp. 35-48.

Broadbent, D. "Attention and the Perception of Speech," 1966 Reprint In Held and Richards (Eds.), Perception, Mechanisms and Models, Freeman, San Francisco, 1972.

Broadbent, D. In Defense of Empirical-Psychology, Methuen and Co., 1973.

Broadbent, D. "Division of Functions and Integration of Behavior," In Schmitt and Worden (Eds.), Neurosciences 3rd Study Program, M.I.T. Press, 1974.

Brown, Eric. "Basis of Reading Acquisitohn," Reading Research Quarterly, Fall 1970.

Brown, R. "Psychology and Reading," In H. Levin and J. Williams (Eds.), Basic Studies in Reading, Basic Books, 1970.

Brown, R. and MacNeill, D. "Tip of the Tongue Phenomenon," Journal of Verbal Learning and Verbal Behavior, 1966, #5, pp. 325-337.

Brubaker, R. "Rate and Pause Characteristics of Oral Reading," Jr. Psych. Research, Vol. 1, #2, 1972.

Busweell, G. "An Experimental Study of Eye-Voice Span," excerpts In Schubert and Torgerson (Eds.), Readings in Reading, T. Crowelle, 1968.

Capranica, R., Frishkopf, L., Coldstein, M. (1967) "Voice and Hearing in the Bullfrog," In Wathen-Dunn (Ed.), Models for the Perception of Speech and Visual Form, M.I.T. Press, 1967.

Cazden, C. "Play with Language and Meta Linguistic Awareness," paper presented at second Lucy Sprague Mitchell Me. Conf. May 19, 1973.

Chall, J. "Research in Linguistics and Reading Instruction: Implications for Further Research and Practice," Reading and Realism, J. Allen Figurel (Ed.), Vol. 13, Part I, Proceedings of the Thirteenth Annual Convention, International Reading Association, Newark Delaware, 1969, pp. 560-571.

Chomsky, N. Aspects of the Theory of Syntax, M.I.T. Press, 1965.

Chomsky, N. Topics in Theory of Generative Grammar, Mouton, 1966.

Chomsky, N. "Formal Nature of Language," In Lenneberg (Ed.), Foundations of Language, Wiley and Sons, 1967.

Chomsky, N. "The General Properties of Language," In Millikin and Darley (Eds.) Brain Mechanism Underlying Language and Speech, Grune and Stratton, 1967.

Chomsky, N. "Phonology and Reading," In Levin and Williams (Eds.), Basic Studies in Reading, Basic Books, 1970.

Chomsky, N. and Halle, M. The Sound Patterns of English, Harper and Row, 1968.

Conrad, R. "Speech and Reading," In Kavanagh and Mattingly (Eds.), Language by Ear and by Eye, M.I.T. Press, 1972.

Cooper, F. "How is Language Conveyed by Speech" In Kavanagh and Mattingly (Eds.), Language by Ear and by Eye, M.I.T. Press, 1972.

Crowder, R. "The Sounds of Vowels and Consonants in Immediate Memory," Journal of Verbal Learning and Verbal Behavior, #10, 1971, pp. 587-596.

Crowder, R. "Visual and Auditory Memory," In Kavanagh and Mattingly (Eds.), Language by Ear and by Eye, M.I.T. Press, 1972.

Crowder, R. and Morton, J. "Precategorical Acoustic Storage," Perception and Psychophysics, Vol. 5, 1969, pp. 365-373.

Crystal, D. and Quirk, R. System of Prosodic and Paralinguistic Features of English, Mouton 1964.

Darwin, J. "Ear Differences and Hemispheric Specialization," In Schmitt and Worden (Eds.), The Neurosciences 3rd Study Program, M.I.T. Press, 1974.

Darwin, J., Turvey, M., Crowder, R. "Dichotic Input of Numbers and Letters," Cognitive Psychology, #3, 1972, pp. 255-267.

Downing, John. Comparative Reading, Macmillan Co., 1973.

Eimas, P., Siqueland, E., Jusczyk, P., Vigorito, J. "Speech Perception in Infants," Science, 1971, pp. 303-306.

Elkonin, D. "Methods of Teaching Reading," J. Downing (Ed.), Comparative Reading, Macmillan, 1973.

Fant, G. "Auditory Patterns of Speech," In W. Dunn (Ed.), Models for Perception of Speech and Visual Form, M.I.T. Press, 1969.

Fantz, R. "The Origin of Form Perception," In Held and Richards (Eds.), Perception: Mechanisms and Models, W.H. Freeman and Co., 1972.

Fay, Warren. Temporal Sequence in Perception of Speech, Mouton, 1966.

Fodor, J., and Bever, T. "The Psychological Realities of Linguistic Segments," In Jakobvitz and Miron (Eds.), Readings in Psychology of Language, Prentice Hall, 1967.

Fromkin, V. "The Non-anomalous Nature of Anomalous Utterances," Language, Vol. 47, March 1971.

Fromkin, V. "Slips of the Tongue," Scientific American, December 1973.

Fry, D., Abramson, A., Eimas, P., Liberman, A. "Identification and Discrimination of Synthetic Vowels," Language and Speech, #5, 1962, pp. 171-187.

Garrett, M., Bever, T., Fodor, J. "The Active Use of Grammar in Speech Perception," Perception and Psychophysics, vol. 1, 1966, pp. 30-32.

Geschwind, N. "The Organization of Language in the Brain," Science, November 12, 1970.

Ghent, Lila. "Form and Its Orientation - A Child's Eye View," American Journal of Psychology, #74, 1961, pp. 177-191.

Gibson, E. "Reading for some Purpose," In Kavanagh and Mattingly (Eds.), Language by Ear and by Eye, M.I.T. Press, 1972.

Gibson, E. and Guinet, L. "Perceptions of Inflections in Brief Visual Presentations of Words," Journal of Verbal Learning and Verbal Behavior, #10, 1971, pp. 182-190.

Gibson, E., Osser, J., Pick, A. "A Study of Development of Grapheme-Phoneme Correspondences," Journal of Verbal Learning and Verbal Behavior, #2, 1963, pp. 142-146.

Gleitman, L. and Rozin, P. "Teaching Reading by Use of a Syllabary," Reading Research Quarterly, September 1973.

Goodman, K. Psycholinguistic Nature of Reading.

Goldman-Eisler, F. "Segmentation of Input in Simultaneous Translation," Journal of Psycholinguistic Research, Vol. 1, #2, 1972.

Goodglass, H. "Developmental Comparison of Vowels and Consonants in Dichotic Listening," Journal of Speech and Hearing, Vol. 16, December 1973.

Goodglass, H., and Peck, E. "Dichotic Ear Order Effects in Korsakoff and Normal Subjects," Neuropsychologia, Vol. 10, pp. 211-217.

Goodman, K.S. (Ed.), "Psycholinguistic Nature of the Reading Process," Wayne State, 1968.

Gough, P. "One Second of Reading," In Kavanagh and Mattingly (Eds.), Language by Eye and by Ear, M.I.T. Press, 1972.

Hebb, D. The Organization of Behavior, Wiley and Sons, 1949.

Held, R. and Richards, W. Perception: Mechanisms and Models, Readings from Scientific American, W.H. Freeman, San Francisco, 1972.

Hess, I. "Imprinting in a Natural Laboratory," Scientific American, August 1972.

Hochberg, J. "Toward a General Theory of Graphic Communication," Project Literacy Reports, November 1965, #5.

Hochberg, J. "Components of Literacy," In H. Levin and J. Williams (Eds.), Basic Studies in Reading, Basic Books, 1970.

Hubel, D. "The Visual Cortex of the Brain," In Held and Richards (Eds.), Perception: Mechanisms and Models, W.H. Freeman and Co., San Francisco, 1972.

Huey, E. The Psychology and Pedagogy of Reading, reprinted by M.I.T. 1968.

Huggins, A., and Klatt, D. "Timing Studies," Quarterly Progress Reports, January 13, 1974.

Jakobson, R., "Franz Boas' Approach to Language," Int. Jr. Am. Linguist. Vol. 10, 1944, pp. 188-197.

Jakobson, R. "Language Universals and Linguistics," In J. Greenberg (Ed.), Universals of Language, M.I.T. 1963.

Jakobson, R. "About the Relation Between Visual and Auditory Signs," In W. Dunn (Ed.), Models for Perception of Speech and Visual Form, M.I.T. 1967.

Jakobson, R. Child Language, Aphasia, and Phonological Universals, Mouton, 1968.

Jakobson, R. and Halle, M. "Phonology and Phonetics," In Roman Jakobson Selected Writings I - Phonological Studies, Mouton, 1962.

Jarvella, R. "Syntactic Processing of Connected Speech," Journal of Verbal Learning and Verbal Behavior, #10, 1971, pp. 409-416.

Johnson, J. and McClelland, J. "Perception of Letters in Words. Seek Not and Ye Shall Find," Science, June 1974, pp. 1192-1193.

Johnson-Laird, P. "The Perception and Memory of Sentences," in J. Lyons (Ed.), New Horizons in Linguistics, Penguin Press, 1970.

Kavanagh, J. Communicating by Language. The Reading Process. Proceedings of Conference on Communicating by Language held February 1968, Health, Education and Welfare, 1970. Includes discussions by Bever, Labov, Hochberg, Gibson, H. Levin, Kavanagh, J. Morton.

Kavanagh, J. and Mattingly, I. Language by Ear and by Eye, M.I.T. Press, 1972.

Kimura, D. "The Asymmetry of the Human Brain," Scientific American, March 1973.

Klima, E. "How Alphabets Might Reflect Language," In Kavanagh and Mattingly (Eds.), Language by Ear and Eye, M.I.T. Press, 1972.

Klopter, P. "On Uniqueness in Behavior," Science, December 21, 1973.

Kolers, P. "Reading as a Perceptual Skill," Project Literacy #1, July 1964.

Kolers, P. "Temporal Effects in the Perception of Light and Form," Wathen-Dunn (Ed.), Models for the Perception of Speech and Visual Form, M.I.T. Press, 1967.

Kolers, P. "Reading Temporally and Spatially Transformed Text," In K. Goodman (Ed.), Psycholinguistic Nature of the Reading Process, Wayne State, 1968.

Kolers, P. "Three Stages of Reading," In Levin and Williams (Eds.), Basic Studies on Reading, Basic Books, 1970.

Kolers, P. and Perkes, D. "Orientation of Letters and their Speed of Recognition," Perception and Psychophysics, Vol. 5, 1960, pp. 275-280.

LaBerge, D. "Beyond Auditory Coding," In Kavanagh and Mattingly (Eds.), Language by Ear and by Eye, M.I.T. Press, 1972.

Lackner, J. and Garrett, M. "Resolving Ambiguity," Cognition, 1972, pp. 359-372.

Labov, W. Discussion in J. Kavanagh (Ed.) Communicating by Language. The Reading Process. Proceedings of Conference on Communicating by Language held February 1968, Health, Education and Welfare, 1970. Includes discussions by Bever, Labov, Hochberg, Gibson, H. Levin, Kavanagh, J. Morton.

Lashley, K. "The Problem of Serial Order in Behavior," S. Saporta (Ed.), Psycholinguistics, Holt, Rinehart and Winston, 1961.

LeFevre, C. "Simplistic Standard-Word-Perception Theory of Reading," E. Everetts (Ed.), Aspects of Reading, National Council of Teachers of English, 1968.

LeFevre, C. "The Simplistic Standard-Word-Perception Theory of Reading," E. Everetts (Ed.), Aspects of Reading, National Council of Teachers, 1967.

Lehiste, Ilse. Suprasegmentals, M.I.T. Press, 1970.

Lenneberg, E. "A Biological Perspective of Language," E. Lenneberg (Ed.) New Directions in the Study of Language, M.I.T. Press, 1966.

Levelt, W. "A Scaling Approach to the Study of Syntactic Relations," In Floes d'Arcais and Levelt (Eds.), Advances in Psycholinguistics, North Holland Publ. Amsterdam, 1970.

Levin, H. "Studies on Various Aspects of Reading," Project Literacy Report, November 1965, #5.

Levin, H. and Cohen, J. "Effects of Instruction on Eye-Voice Span," Preliminary Draft, 1967.

Levin, H. and Turner, E. "Sentence Structure and the Eye-Voice Span," Preliminary Draft, September 1966.

Levin, H. and Kaplan, E. "Grammatical Structure and Reading," In Levin and Williams (Eds.), Basic Studies on Reading, Basic Books, 1970.

Liberman, A., Delattre, P., Cooper, F. "The Role of Selected Stimulus Variables in the Perception of Unvoiced Stops," American Journal of Psychology, October 1952, pp. 497-516.

Liberman, A. Speech to Academy of Aphasiain, Boston, September 29, 1969.

Liberman, A. "The Grammars of Speech and Language," Cognitive Psychology, Vol. 1, October 1970.

Liberman, A. M.I.T. talk, March 21, 1974a.

Liberman, A. "Specialization of the Language Hemisphere," Schmitt and Worden (Eds.), Neurosciences. 3rd Study Program, M.I.T. Press, 1974b.

Liberman, A., Cooper, F., Harris, K., MacNeilage, P., Stockholm Speech, September 1962.

Liberman, A., Cooper, F., Harris, K., MacNeilage, P., Studdert-Kennedy, M. "Some Observations on a Model for Speech Perception," In W. Dunn (Ed.), Models for Perception of Speech and Visual Form, M.I.T. Press, 1967.

Liberman, A., Mattingly, I., Turvey, M. "Language Codes and Memory Codes," In Melton and Martin (Eds.), Coding Processes in Human Memory, Winston and Sons, 1972.

Liberman, I. "Speech and Lateralization of Language," Bulletin of the Orton Society, XXI, 1971.

Liberman, I. "Segmentation of the Spoken Word and Reading Acquisition," Bulletin of the Orton Society, XXIII, 1973.

Lieberman, P. "Intonation, Perception and Language," M.I.T. Research Monograph, 1967.

Lieberman, P. "Intonation and the Syntactic Processing of Speech," In W. Sunn (Ed.), Models for Perception of Speech and Visual Form, M.I.T. Press, 1967.

Lieberman, P. "On Evolution of Language," Cognition, Vol. 2, 1973, pp. 59-94.

Lindsay, P. and Norman, D. Human Information Processing, Academic Press, 1972.

Luria, A. Higher Cortical Functions in Man, Basic Books, 1966.

MacKay, D. "Ways of Looking at Perception," In W. Dunn (Ed.), Models for Perception of Speech and Visual Form, M.I.T. Press, 1967.

MacKay, D. "Neural Communication, Exp. and Theory," In W. Uttal (Ed.), Sensory Coding - Selected Readings, Little Brown, 1972.

Malmberg, Bertil. Phonetics, Dover Publishing, 1963.

Marchbanks, G. and Levin, H. "Cues by which Children Recognize Words," Jr. Ed. Psych., Vol. 56, 1965, pp. 57-61.

Masland, R., "Implications for Therapy," Young and Lindsley (Eds.), Early Experience in Visual Information Processing, National Ac. Science, 1970.

Mattingly, I. "Reading, the Linguistic Process and Linguistic Awareness," In Kavanagh and Mattingly (Eds.), Language by Ear and by Eye, M.I.T. Press, 1972.

Michael, C. "Retinal Processing of Visual Images," In Held and Richards (Eds.), Perception: Models and Mechanism, Freeman, 1972.

Miller, George. "Magic #7," Psych. Review, Vol. 63, 1956, pp. 81-97.

Miller, George. "Information and Memory," August 1956, reprinted in Held and Richards, Perception: Mechanisms and Models, W. Freeman, 1972.

Miller, George. Language and Communication, McGraw Hill, 1951.

Miller, George. "Some Preliminaries to Psycholinguistics," In L. Jakobvits and M. Miron (Eds.), Readings in Psychology of Language, Prentice Hall, 1967.

Miller, George, and Isard, S. "Some Perceptual Consequences of Linguistic Rules," Journal of Verbal Learning and Verbal Behavior, #2, 1963, pp. 217-228.

Miller, George and McNeill, D. "Psycholinguistics" In G. Lindzey and E. Aronson (Eds.), The Handbook of Social Psychology, 2nd ed., Vol. 3, Addison-Wesley, 1969.

Miller, George and Nicely, P. "An Analysis of Perceptual Confusions Among Some English Consonants," in S. Saporta (Ed.), Psycholinguistics, Holt, Rinehart and Winston, 1961.

Miller, G., and Selfridge, J. "Verbal Context and Recall of Meaningful Material," In S. Saporta (Ed.), Psycholinguistics, Holt, Rinehart and Winston, 1961.

Milner, B. "Hemispheric Specialization," In F. Schmitt and F. Worden (Eds.), The Neurosciences - 3rd Study Program, M.I.T. Press, 1974.

Miron, M. and Brown, E. "Comprehension and Rate Incremental Aura. Coding," Jr. of Psycholinguistic Research, Vol. 1, 1971, pp. 65-77.

Miyawaki, Liberman, A., Fujimura, O., Strang, Jenkins. "Cross Language Study in Perception of F_3 Cue to "r" and "l". Paper for XX Int. Congr. of Psych., Tokyo, 1972.

Morton, J. "A Model for Continuous Language Behavior," Language and Speech, Vol. 7, 1964, pp. 40-70.

Morton, J. and Broadbent, D. "Passive Versus Active Recognition Models," In W. Dunn (Ed.), Models for Perception of Speech and Visual Form, M.I.T. Press, 1967.

Myerson, R. and Goodglass, H. "Transformational Grammars of Three Agrammatic Patients," Language and Speech, Vol. 15, 1972, pp. 40-50.

Muntz, W. "Vision in Frogs," In Held and Richards (Eds.), Perception: Mechanisms and Models, Freeman, 1972.

Neisser, U. Cognitive Psychology, Appleton Century Crofts, 1967.

Orr, D., Friedman, H., Williams, J. "Trainability of Listening Comprehension of Speeded Discourse," J. Ed. Psych. #56, 1965, pp. 148-156.

Paivio, A. Imagery and Verbal Processes, Holt, Rinehart and Winston, 1971.

Paivio, A. "Imagery and Deep Structure in the Recall of English Nominalizations," Journal of Verbal Learning and Verbal Behavior, #10, 1971, 1-12.

Pritchard, R. "Stabilized Images on the Retina," reprint from June 1961, Scientific American in Held and Richards (Eds.), Perception: Mechanisms and Models, Freeman, 1972.

Read, C. "Children's Perceptions of the Sounds of English," Doctoral Thesis in Graduate School of Education at Harvard University, August 1970.

Rock, I. "The Perception of Distorted Figures," Scientific American, January 1974.

Rubenstein, H., Garfield, L., Millikan, J. "Homographic Entries in the Internal Lexicon," Journal of Verbal Learning and Verbal Behavior, #9, 1970, pp. 487-494.

Rumelhart, D. "A Multicomponent Theory of Confusion Amohg Briefly Exposed Alphabetic Characters," University of California, LaJolla, November 1971.

Rumelhart, D. and Siple, P. "The Process of Recognizing Tachistoscopically Presented Words," LaJolla, Calif., August 1972.

Sasanuma, S. and Fujimura, O. "Selective Impairment of Phonetic and Non-phonetic Transcription of Words in Japanese Patients," Cortex, March 1971, Vol. vii.

Schuell, H., and Jenkins, J. "The Nature of Language Deficit in Aphasia," In Saporta (Ed.), Psycholinguistics, Holt, Rinehart and Winston, 1961.

Selfridge, O. and Neisser, U. "Pandemonium Recognition by Machine," In Held and Richards (Eds.), Perception: Mechanisms and Models, Freeman, 1972.

Shankweller, D. and Liberman, I. "Misreading," A Search for Causes, In Kavanagh and Mattingly (Eds.), Language by Ear and by Eye, M.I.T. Press, 1972.

Smith, F. "An Analysis of Fluent Reading," Reading Research Quarterly, Spring 1971.

Snodgrass, J., Wasser, B., Finkelstein, M. "On the Fate of Visual and Verbal Memory Codes for Pictures and Words," Journal of Verbal Learning and Verbal Behavior, #13, 1974, pp. 27-37.

Spellacy, F. and Blumstein, S. "The Influence of Language Set on Ear Preference in Phoneme Recognition," Cortex, Vol. 6, 1970, pp. 430-439.

Stevens, K. "The Role of Formant Transitions in the Voice-Voiceless Distinction for Stops," Quarterly Progress Report, #101, April 15, 1971.

Stevens, K. "Research Objectives and Summary of Quantal Places for Articulation of Consonants," Quarterly Progress Reports, #108, January 15, 1973.

Stevens, K. "Potential Role of Property Detectors in the Perception of Consonants," Quarterly Progress Reports, #101, July 15, 1973.

Stevens, K., and Halle, M. "Remarks on Analysis by Synthesis and Distinctive Features," In W. Dunn (Ed.), Models for Perception of Speech and Visual Form, M.I.T. Press, 1967.

Stewart, M. and Gough, J. "Word Recognition Latency as a Function of Word Length," Paper for MPA, 1969.

Sticht, T.G. "Learning by Listening," In J. Carroll (Ed.), Language Comprehension and Acquisition of Knowledge, Holt, Rinehart and Winston, 1972.

Studdert-Kennedy, M., and Hadding, K. "Auditory and Linguistic Processes in Perception of Intonation Contours," Language and Speech, Vol. 6, October 1973.

Teuber, H. "Why Two Brains?" Schmitt and Worden (Eds.), Neurosciences 3rd Study Program, M.I.T. Press, 1974.

Thorndike, E. "Reading as Reasoning," reprint from 1917 In Reading Research Quarterly, Summer 1971.

Turvey, M. "On Peripheral and Central Processes in Vision," Psychological Review, Vol. 80, 1973, pp. 1-52.

Uttal, W. "Emerging Principles of Sensory Coding," In W. Uttal (Ed.), Sensory Coding - Selected Readings, Little Brown, 1972.

VonStockert, T. "Recognition of Syntactic Structure in Aphasic Patients," Cortex, September 1972, pp. 323-

Warren, R. "Perceptual Restoration of Missing Speech Sounds," Science, 1967, p. 392.

Weber, R. "Study of Oral Reading Error," Reading Research Quarterly, Fall 1968.

Weber, R. "Analysis of First Grade Oral Reading Errors," Reading Research Quarterly, Spring 1970.

Weber, R. "First-Graders' Use of Grammatical Context in Reading," In Levin and Williams (Eds.), Basic Studies on Reading, Basic Books, 1970.

Wheet, H. "The Nature of Recognition," reprinted in D. Schubert and T. Torgerson (Eds.), Readings in Reading, T. Crowell Co., 1968.

Woodworth, R., and Schlosberg, H. Experimental Psychology, Revised edition, Holt, Rinehart and Winston, 1958.

Zhurova, L. In Soviet Psychology and Psychiatry, Vol. 2, 1963, pp. 17-27.

Zurif, E., Caramazza, A., Myerson, R. "Grammatical Judgments of Agrammatic Aphasics," Neuropsychologia, Vol. 10, 1972, pp. 405-417.